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THE PHYSICAL METHODS APPLIED IN PLEISTOCENE RESEARCH IN HUNGARY

By

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The complexity of the geohistorical sciences increases as we approach the present along the geological time scale. In this respect three main phases can be distinguished. 1. Pre-Cambrian research with mainly petrographic and geochemical methods, 2. the study of the Palaeozoic-Mesozoic-Tertiary, where palaeontology is also added to the above, and 3. Quaternary research, including besides the above-mentioned disciplines also geomorphology and the disciplines connected with the appearance of Man.

Hungary has been established as a region particularly suited to methodological studies in Quaternary research, because of the thickness and diversity of its Quaternary deposits, as well as owing to its peculiar geotumour tectonics. It was in this country that the three phases of river-activity were first established. In ancient deposits this feature can be determined, to a certain extent together with relief energy, by establishing diverse indices of maturity derived from the mineral constitution of the deposits. The two-peak grain size distribution curve, characteristic of the fluvial deposits as it was first recognized within the Carpathian Basin, proved a distinctive fluvial feature of general validity (Fig. 3). The method of measuring grain shape independently of the substantial features of the grain by the *cpv* method permits the determination of the distance of fluvial transport (Fig. 2), the distinguishing of river-terraces (Table), and the separation of aeolian, fluvial and glacial deposits (Fig. 1). The study of the Hungarian rivers considerably furthered the methods of establishing current directions out of the cross stratification (Fig. 4). The demonstration of southeast European periglacial periods by pseudo-stratification (cryoturbation) phenomena started from here, too. Complex sedimentological and morphological research led to the recognition of derasional valley and to the development of new methods of geomorphological mapping. The classification of surfaces by the *cpv* method provide possibility to advanced geomorphological morphometry (Fig. 5).

At present in Hungary attempts are made in organizing a new type of cooperation between the diverse disciplines of the Earth sciences.

Pleistocene research is one of the most composite branches of natural science. As we approach the present on the geological time scale, the complexity of the geohistorical disciplines is seen to increase.

The methods best suited to the study of the earliest pre-Cambrian periods are those of petrography and geochemistry. It is due to these methods that the early stages of the evolution of the Earth can be reconstructed at all from the largely metamorphized rocks. However, some of the less intensely metamorphosed formations can occasionally be subjected to a paleoclimatological evaluations as well.

The next large unit of Earth history as distinguished on a methodological basis, extends from about the Cambrian to the end of the Tertiary. The geochemical-petrological-paleoclimatological approach is enriched in this period

by stratigraphic and paleontologic methods, thus together constituting the classic "geological" approach in the narrower sense. Besides the equilibrium of denudation and accumulation and the finer details in time and space of marine, and to a lesser extent of terrestrial sedimentation, it is the evolution of life and the effect of the organic substances in large scale production, that becomes the central problem, accompanied by diversified interrelations of adjacent magmatic and sedimentary complexes.

Another abrupt increase in the complexity of research is represented by the study of the Pleistocene. New methods of investigation are required due to the presence of terrestrial deposits (more or less completely destroyed in earlier times) and by the presence of tool-making, fire-building Man. As a consequence, the geochemical, petrographical, stratigraphical and paleobiological viewpoints are accompanied by geomorphologic, lithologic, xylotomic, archeologic and anthropologic ones. The result is once more a well-defined branch of science, namely Quaternary research.

The complexity of Quaternary research as a whole, entails the complexity of the methodology employed. These methods frequently have far-reaching effects on the other branches of science. They facilitate the proper evaluation of the phenomena obscured by diagenesis and metamorphism of the earlier periods. Quaternary research thus teaches the classic geohistory, elucidates the laws of sedimentation and relief evolution and shows how to utilize systematically each other's results in building up a higher level of geological consciousness.

The method however, is bred by the material to be examined, by the region to be studied. There are certain geographic regions particularly well suited to give rise to theorems of general validity. Such a region is Hungary resp. the Carpathian Basin, whose importance in Quaternary research, in the development of its methodology is far exceeding the relative size of the area.

Hungary is a representative of a type of area, relatively rare on the globe, which lends itself particularly well to the recognition of large-scale interrelations between different phenomena of nature. It is neither a tableland nor a folded region, nor can it — as against former notions — be considered a transitional type between the two. Recent research [15] has established that Hungary together with the rest of the Carpathian Basin is the finest example of the geotumour structure relatively rare on a world-wide scale, being mostly covered by the seas. The geotumour in the narrower sense is characterized by its intermediate position between the primary oceanic and the more continental secondary zones of orogenesis, by an elevation of the upper mantle, by the appropriate thinning out of the crust and by an uncommonly intense serorogenic volcanism on the side of the secondary zone of orogenesis.

Up to now this type of structure was interpreted largely as a resistent core ("Zwischengebirge", "median mass") between the folded chains and was

considered to represent a remnant of slightly enhanced mobility of the rags of shield caught between the fold chains.

According to the new results, however, the Carpathian Basin is to be interpreted as a series of zonal attenuations of the crust with corresponding zones of sedimentation on the surface, passing at a later stage of the evolution into more or less closed basins. Igneous, metamorphic and sedimentary rock and ore genesis, the geothermal, hydrogeological, climatic and geomorphologic conditions sharply differ, in consequence, from those of both the tablelands and the fold chains [17]. (As to the special characteristics of the Pleistocene evolutions see the next paper of this volume by KRETZOI—PÉCSI.)

The chain of the Carpathian Mountains is also partly due to the geotumour. On the nearly horizontal gliding surfaces lubricated by the moisture content emanating from the rocks during the orogenic periods, masses of rock advance under the pull of gravity towards the periphery of the geotumour, being gradually folded up in the process. This "tectonic denudation" and the thinning out of the crust culminates in the Cretaceous. Oval basins controlled by the retreat of the crust-mantle interface into greater depth are developed in the Neogene. The frame of the Carpathian Mountains turned out a bulwark that holds off physical and biological invasion on the surface. Denudation and deposition are more sharply delimited and the geomorphologic, meteorologic and even some of the biologic factors exhibit an increased degree of coherence.

In consequence of this coherence the interrelations between different phenomena are here especially clear. This led Hungarian Pleistocene research to the development of many a method and statements that gained large-scale acceptation.

One of the results also important on an international scale, was the recognition of the *three types of stream phases*, i.e. the establishing of the rapports between the energy of the river on the one hand and its load on the other. These studies by J. CHOLNOKY [1] were closely connected with the hidrographic survey of the Hungarian rivers.

In older deposits these phases of river activity may be recognized by the indices of maturity deduced from the mineralogical constitution of the deposite.

The joint study of lithological and physiographic phenomena in the Little Hungarian Basin under the consideration of paleontological viewpoints resulted in an early *parallelization of the river-terrace sequences of the areas of relative uplift, with the* normal filling of the *relatively subsiding regions* [14], the constituting series becoming regularly younger downwards in the first instance and upwards in the second.

The closed basins offered an excellent opportunity to study the relations between the load of the rivers, the nature of denudation, and the distance traveled by the load. The majority of the rocks and minerals of which the pebbles and sand grains consist being anisotropic, the grain shape developed

as a result of wear is determined partly by this anisotropy. *The evaluation of the grain shape* is carried out by most of the methods with disregard for the factor of anisotropy. One group of these methods defines grain shape by the ratio of the longest, shortest and medium diameter, another by the radii of curvature, the third by the ratio of volume to the surface. (The latter, instead of measuring the surface, employs in fact the longest diameter equal to the radius of the circumscribed sphere.) Every one of these methods is aimed at determining isometry, the degree of approximation of a perfect sphere, just like

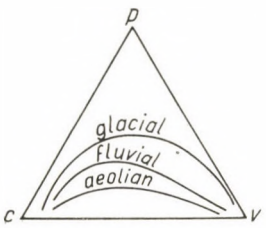

Fig. 1

the approximative methods distinguishing 3 to 6 vaguely defined visual classes [3, 9, 10]. However, the result of maximum wear is a sphere but in the case when the substance in question is isotropic, being an ellipsoid of rotation of a triaxial ellipsoid in every other case.

The only method determining the intensity of wear independently of the substantial features of the grain [4, 11, 12, 16], first introduced in Hungary, determines the ratios between the concave, plane and convex surfaces (cpv percent values). As a result it not only offers the distance of transportation of the sediment but the distinction of glacial, fluvial and aeolian deposits as well. The one-sided wear (the *p* number indicating the prevalence of plane surfaces) is largest in the case of glacial, smallest in the case of aeolian transport (Fig. 1).

In order to gain a sufficient number of values permitting a statistical treatment most authors contented themselves with the four-class visual estimation introduced in 1920 [3, 9, 10]. Studies, however, revealed [5] that a ten-class visual determination, standing on the exact theoretical footing of the cpv-method is not more time-consuming in consequence of the decreasing number of necessary measurements with increasing accuracy. Moreover, the furnished results permit an insight into the evolution of the river in time and space, bringing out the finer changes of the mean load transport distance with the increase of the length of the stream proper (Fig. 2), its eventual decrease as a result of the discharge of the tributaries. It also permits the distinction of the individual terraces of the vertical terrace sequence [5] — thus resolving also the problem of terrace parallelization — and to characterize

the historical evolution of the rivers. In this respect the Danube and particularly its Hungarian section is among the best studied big rivers of the world [6].

Further essential but even less well known results were attained in Hungarian Quaternary research in the *field of grain size distribution* studies, and in consequence in the distinction of the genetic types of deposition, too

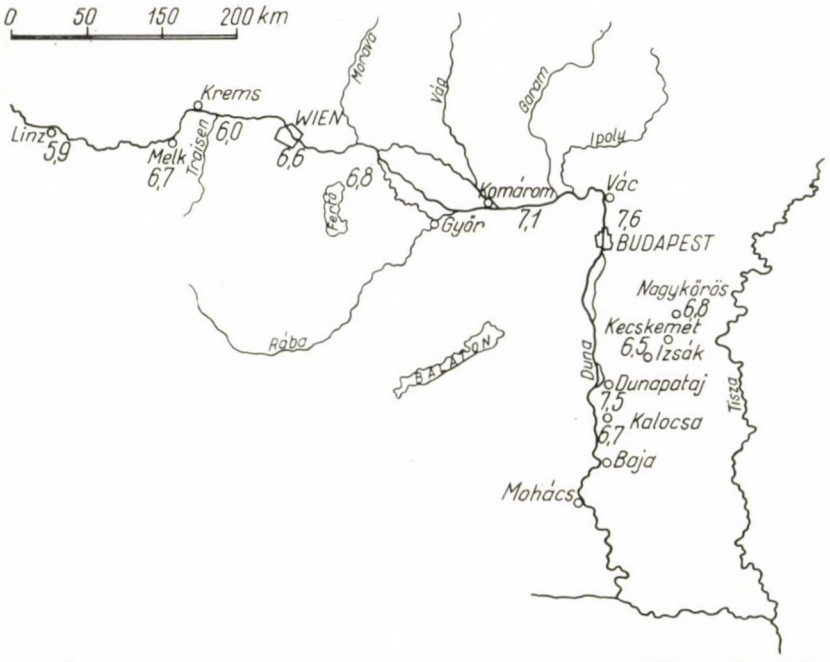

Fig. 2. $v + \frac{1}{2}$ p values of the 10 to 15 mm size quartz fraction of Danube gravel after É. PÉCSI—DONÁTH

	Mean	Holocene	late Pleistocene				early Pleistocene		Pliocene	
			Würm	Riss-Würm	Riss	Mindel	Günz		pre-Günz	
		I	II/a	II/b	III	IV	V	VI	VII	VIII
		Numbers of terraces								
Linz	5.9	6.1	6.1	—	5.6	5.9	—	5.9	5.6	6.1
Melk	6.7	7.1	6.5	6.0	—	7.1	—	—	7.0	—
Krems	6.0	—	5.0	—	5.6	—	6.4	6.1	7.1	—
Wien	6.6	—	6.1	6.6	6.5	6.4	—	6.2	7.4	7.1
Lake Fertő	6.8	7.2	7.1	—	6.8	6.5	6.6	6.2	7.0	—
Komárom	7.1	7.7	7.2	7.3	7.2	6.9	6.8	6.5	7.5	—
Budapest	7.6	7.5	7.6	8.0	7.6	7.3	—	—	—	—
Nagykőrös	6.8	—	—	—	—	6.8	6.8	—	—	—

[14]. The most important achievement is the establishing of the two-maximum distribution graphs of the river-laid deposits with a peak in the finer classes at 0.1 to 0.4 mm and one somewhere in the coarser classes. This is an important distinguishing feature against the well-sorted Gaussian-type one-peak distribution of the see-shore and aeolian deposits (Fig. 3). The peak in the finer class of the river-deposits presumably substantially represents the suspended load, while the coarser one represents essentially the rolled load, which changes along with the local environment of the stream. In the fluvial deposits of the first intra-Carpathian basin of the Danube and its tributaries

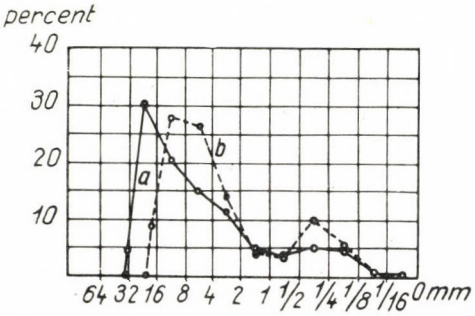

Fig. 3. Two-peak grain size distribution of different parts of fluvial strata (Danube gravel by Feketeerdő, Hungary) *a)* coarse grained stratum with horizontal stratification; *b)* finer grained stratum with diagonal stratification

(the Little Hungarian Plain) the coarse maximum frequently overtops the other one, but in the Great Plains and to a smaller extent also in the Little Plain the majority of the fluvial deposits is characterized by the dominance of the fine-grain peak, with the coarse-grain one just representing an asymmetry of the distribution graph (see the paper by RÓNAI in this volume).

In the study of *porosity and permeability*, of considerable importance for hydrocarbon and water prospecting as well as for research on the migration of the elements, up-to-date methodological results have been obtained by the Oil Exploitation Laboratory of the Hungarian Academy of Sciences in Miskolc.

Also the systematic determination of the strength of the Pleistocene deposits carries some useful implications besides settlement planning and construction engineering also for theoretical research. A classification of utility also in the field for the characterization of these largely low-strength deposits is as follows [14]:

1. the deposit is completely unconsolidated,

2. there is some adhesion between the grains but by excavation the deposit crumbles under its own weight,

3. the deposit does not crumble under its own weight, but the grains can be separated by hand,

Fig. 4. Gravel sheets and current directions as established by cross stratification analysis in the Little Hungarian Plains (E. Szádeczky-Kardoss, 1938). I. Old gravel terraces of the Rába river, II. Younger (early) Pleistocene terrace of the right bank of the Rába river, III. Youngest (late Pleistocene) terrace of the left bank of the Rába river, IV. Old terrace of the Gyöngyös river, V. Younger terrace of the Gyöngyös river, VI. Gravel sheet of the Répce river, VII. Pleistocene gravel sheet of the Ikva river, VIII. Area of the Pleistocene gravel deposits of the Marcal river, IX. Young pleistocene alluvial fan of the Rába and Répce rivers, X. Old terraces of the Danube, XI. Young (late Pleistocene) terraces of the Danube; → Current direction as revealed by cross stratification analysis

4. the separation of the grains, impossible by hand, necessitates some implement,

5. the comminution of the deposit requires a force that breaks up some of the quartz grains as well.

In practice, classes 1 to 3 correspond to the usual terms sand and gravel, 4 and 5 to the terms sandstone and conglomerate. Of course, the exact definition of the strength of these latter requires instrumental measurements.

It is a general knowledge that *the slope of cross stratification* is a function of the current vector of the medium of deposition. The Hungarian territory proved to be excellently suited for establishing genetic and methodologic statements concerning this point and their application in the evaluation of the fluvial deposits of Pleistocene age [14]. The directions of the current of the tributaries of the Danube and other streams which built up the vast alluvial fan of the Little Plain (Fig. 4), could be determined essentially by measuring the cross stratification against the adjacent horizontal (or nearly-horizontal) normally stratified layers. The methods developed in this area found some

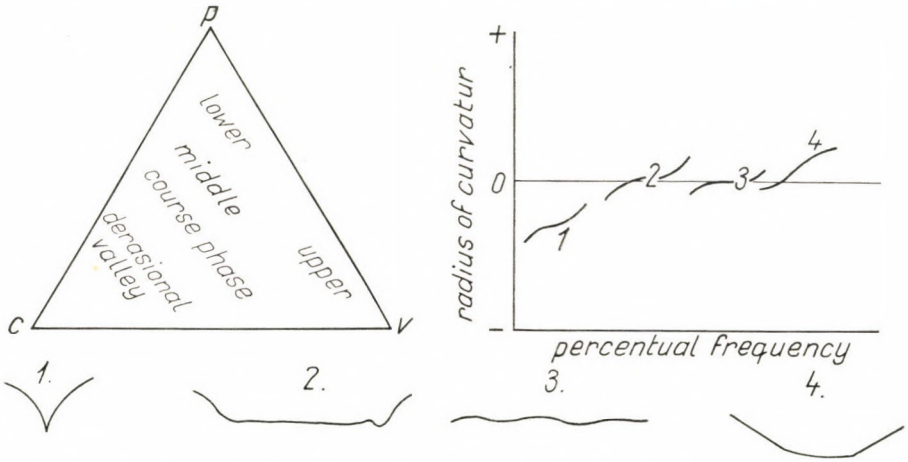

Fig. 5. Cross sections of river valley: 1. — upper course phase, 2. — middle course phase, 3. — lower course phase, 4. — derasional valley

practical application in determining the source area of the sedimentary uranium deposits, namely the location of the primary ore bodies by reconstructing the Permian drainage pattern in South-Hungary. The method of cross-stratification analysis opens up as yet unexploited further opportunities, for the solution of some of the lithologic problems in Hungarian Great Plain Pleistocene deposits.

A discipline connected with the study of cross-stratification is the study of *pseudo- or secondary stratification.* The recognition that the peculiar so-called baggy structures of young gravel deposits are a periglacial solifluctional-*cryoturbational phenomenon* has a decisive importance in the southeast European Pleistocene research. As a result, Hungary and considerable parts of the adjacent countries have been incorporated into the periglacial zone characterized by permanently frozen ground during the glacial phases of the Pleistocene. This statement, at first unbelievable to some of the workers in this field, has become a fundamental concept in the Quaternary research in the region in question. Besides the skeletal soils, a number of other features of solifluction

and flat-tundra phenomena such as ice wedges, frost veins and frost combs, etc. also have been described.

From that time onwards the most substantial advance has been made in the field of *complex microlithologic-geomorphologic studies*. It was on this basis that M. PÉCSI recognized the phenomenon of *corrasional* (more precisely, *derasional) valley* formation and its considerable extent, over about 70 per cent of the low hummocky areas of this country. According to PÉCSI the huge volume of congelifractate sediment over the permanently frozen ground underwent large-scale solifluction in the late spring and early summer phases of thawing, — a process that produced areal slope sculpture and derasional valleys (Fig. 5).

It was these results that most of all permitted the initiation of a detailed *geomorphologic* (physiographic) *mapping* in Hungary [7] and also the current attempts at the *systematization of Pleistocene land forms* (see papers by RÓNAI and PÉCSI).

An important part in Quaternary research might eventually be played by exact morphometry. The study of the large-scale forms began on the basis of W. PENCK's morphological analysis [8]. The problem of morphometry is however in a certain relation with the methods of grain-shape study, as in this case also the fundamental facts are the ratios of convex, plane and concave surfaces. Further advances are to be predicted in the direction of determining these ratios on aerial photographs and also in the evaluation of their radii of curvature (Fig. 5).

One of the most important tools of the recent advances in Quaternary research is radioactive dating. Besides the often-used *radiocarbon method*, also the results obtained by M. FÖLDVÁRI-VOGL and M. KRETZOI [2] in the critical study of the fluorine content of bones are worthy of note. These authors have proved the rate of increase of the fluorine content to depend largely on the nature of the enclosing rock.

In the recent geotumour model [15] of the Carpathian Basins, the *methodological problems* of the mutually invigorating cooperation of the geophysical, volcanological, petrological, lithological, geomorphological, meteorological and even paleobiological sciences also occupy an important place. The Class of Earth Sciences, being organized within the Hungarian Academy of Sciences also intends to pay considerable attention to these methodological problems in the organization of sciences.

REFERENCES

1. Cholnoky, J.: Über Flusstäler. Mitt. Geogr. Ges. Wien, 1927. — 2. Földvári-Vogl, M. — Kretzoi, M.: Geoch. Conf. of the Hung. Acad. Sci. Budapest **69,** 1959. — 3. Guggenmoos, T.: N. Jb. Min. Paläont. Abt. B. Beil. Band **72,** 429, 1934. — 4. Lüttig, G.: Eiszeitalter und Gegenwart **7,** 13—20, 1956. — 5. É. Pécsi—Donáth: Földt. Közlöny **88,** 57—75, 1958. — 6. Pécsi, M.: A magyarországi Dunavölgy kialakulása és felszínalaktana. (Evolution and relief of the Hungarian section of the Danube valley.) Akadémia kiadó, Budapest, 1959. — 7. Pécsi, M. et. al.: Ten years of physical-geographic research in Hungary. Akadémiai Kiadó, Budapest, 1964. — 8. Penck, W.: Die morphologische Analyse, Stuttgart, 1924.— 9. Powers, M. C.: J. Sed. Petr. **23,** 117—120, 1953. — 10. Russel, R. D.—Taylor, R. E.: Am. J. Geol. **45,** 225—267, 1937. — 11. Schneiderhöhn, P.: Heidelb. Beitr. Min. Petr. **45,** 172—191, 1954. — 12. Szádeczky-Kardoss, E.: Centralbl. f. Min. usw. **B.** 389, 1933. — 13. Szádeczky-Kardoss, E.: Földt. Közlöny **66,** 213—226, 1936. — 14. Szádeczky-Kardoss, E.: Geologie der rumpfungarländischen Kleinen Tiefebene. Sopron, 1938. — 15. Szádeczky-Kardoss, E.: Acta Geol. **8,** 433—454, 1964. — 16. Zingg, Th.: Schweiz. Min. Petr. Mitt. **15,** 39—140, 1935. — 17. Szádeczky-Kardoss, E.: VII. Session Assoc. Carpato—Balcanique Sofia, 1965 (In press).

ФИЗИЧЕСКИЕ МЕТОДЫ ИЗУЧЕНИЯ ПЛЕЙСТОЦЕНОВЫХ ОТЛОЖЕНИЙ ВЕНГРИИ

Э. САДЕЦКИ-КАРДОШ

Резюме

Комплексность геологических наук усиливается по мере приближения к голоцену их предмета. В таком отношении можно выделить 3 основные стадии. 1. Изучение докембрия, охарактеризуемое главным образом петрографическими и геохимическими исследованиями; 2. изучение палеозоя, мезозоя и третичной системы с систематически проводимыми палеонтологическими исследованиями и 3. изучение четвертичных отложений, включающее кроме вышеупомянутых исследований также и детальные геоморфологические и связанные с появлением человека исследования.

В связи с большой мощностью и с большим разнообразием четвертичных отложений Венгрии, а также со специальными особенностями, обусловленными своеобразной тектоникой типа «геотумор»-а, Венгрия оказалась особенно выгодной областью для методических исследований по четвертичной системе. Таким образом удалось выделить три разных типа по характеру участков течения рек. Для более древних отложений это можно было сделать с некоторым приближением при помощи различных индексов зрелости, установленных по минералогическому составу пород, причем одновременно делались до определенной степени также и выводы в отношении рельефной энергии. В настоящее время новым отличительным признаком речных осадков можно считать уже всеобщей характерной чертой (рис. 3) кривую распределения гранулометрического состава с двумя максимумами, обнаруженную для соответствующих осадков Карпатского бассейна. Метод измерения формы зерен величинами cpv независимо от вещественных свойств зерна, внедряется уже в широкой международной практике. Это позволяет определить расстояние транспорта наносов рекой, различать речные террасы (рис. 2) и выделить разные типы осадков — эоловые, речные и гляциальные (рис. 1). Изучение рек Венгрии значительно способствовало и определению направления потока на основания косослоистости (рис. 4). Здесь взяли свое начало исследования, которые привели соответственно к выделению перигляциальных периодов на территории Юговосточной Европы путем выявления вторичных слоистостей или криотурбационных признаков.

Комплексные седиментологические и геоморфологические исследования привели к опознаванию в Венгрии процесса формирования деразионных долин, а также к разработке новой методики геоморфологического картирования. Существуют предпосылки для развития нового направления исследований и в области морфометрии, базируясь до некоторой степени на определение соотношений, аналогичных измеренным величинам формы зерен (рис. 5). В настоящее время в Венгрии проявляются инициативы по развитию прямой кооперации геологических наук, которая будет несомненно плодотворной для всех кооперирующих дисциплин.

NATURE AND ASPECTS OF THE QUATERNARY IN HUNGARY

By

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The Quaternary history of Hungary exhibits some intensely azonal features due to a complicated series of tectonic events on the one hand and to the wreath of the Carpathian Mountains surrounding the basin, on the other.

Young tectonic events resulted in the evolution of the Quaternary deposits in three different ways in three distinct regional units, namely:

1. Incomplete, thin Pleistocene series, bearing the traces of a periglacial climate, in the mountains uplifted in Pleistocene times.
2. A Pleistocene sedimentary series locally exceeding 1000 metres in the eastern part and in the northwestern corner of the country.
3. A loess and loam series covering the hummocky regions of Western Hungary and the foothills of the Hungarian Mountains.

In the course of the Quaternary the Hungarian region was characterized by peculiar periglacial conditions, with alternating continental and oceanic climatic oscillations; in the beginning, biogeographic links were strong with the east but later on the flora and fauna exhibited increasing affinity with the west.

The physiographic characteristics of Hungary, displaying a number of markedly azonal features today, were in the Pleistocene also markedly different in a number of respects from the regions exhibiting a well-defined climatic-physiographic zonality. The surrounding wreath of mountains underwent an uplift of considerable amplitude in the Quaternary, while the individual parts of the basin, subject to tectonic movements of varying intensity in space and time, gradually became distinct units sharply delimited against each other (for more details see the paper by SZÁDECZKY-KARDOSS). In the course of the Quaternary, tectonic movements substantially contributed to the modification of the dynamism of zonal climato-morphologic processes; moreover, the uplift of certain regions resulted in the evolution of a set of vertical climato-morphologic zones.

The young tectonic evolution in the Neogene and particularly in the Pleistocene led to the formation of two distinct permanent basins of accumulation (the Little and the Great Hungarian Plains). The two basins are separated by a mountain chain of SW—NE strike consisting of Mesozoic fault blocks and young Tertiary volcanics, whose peaks rise but seldom above the height of 1000 metres. This latter structural and morphologic unit grades west of the Danube into an extended region of low hummocks.

In dependence on the above three large structural-morphologic units, the Quaternary deposits and landscapes of Hungary fall into three distinct genetic categories.

1. The Hungarian Mountains of SW—NE strike attained their present elevation of 500 to 1000 metres in the course of the Pleistocene. On the foothills of this mountain chain, the deposits of the Pliocene — Pannonian — "sea" of gradually decreasing salinity, representing the last inundation of the Carpathian Basin, lie at a mean level of about 300 metres (which reaches 400 metres in some places, and even 600 metres in the west, namely in the Graz embayment of the East Alps). It was the position of these deposits and of the late Pliocene and early Pleistocene terraces of the Danube that permitted to establish the uplift of the Hungarian Mountains since the upper Pliocene. The Mesozoic fault blocks of Transdanubia, of about 500 metres mean elevation today, grew to mountain height in the course of the Quaternary. The uplift caused the formation of deeply incised valleys featuring a large number of terraces (5 to 7) in the mountainous sections of the Danube, Zagyva and Hernád rivers and the deposition of vast alluvial fans in the foreland of the mountains. From the point of view of relief evolution, the most important role was played by the late Mindel (Mindel-Riss) phase of uplift, the strongest phase within the entire Pleistocene.

The abrupt increases in relief energy resulted in the formation of periodically renewed slopes, dissected in the course of the interglacials by erosional valleys, and sculpted during the dry cold glacials by cryoplanation, nivation and the formation of flat embryonal derasional valleys (dells), bringing forth piedmont surfaces and cryoplanational terraces, etc. On the plateaux, congelifraction produced thick covers of eluvial scree (for details see the paper by SZÉKELY). As a result of periglacial congelifraction, the slopes became covered with boulder fields, thick scree, eluvial-colluvial loam and loess-like deposits. The fine rock flour produced by cryofraction was deposited by the glacial winds on the lee slopes of the small intermontane basins and repeatedly reworked by slopewash and solifluction. (For details see the paper by PÉCSI.) The forest soils consisting of clayey and loamy substances, formed on the surfaces and slopes of the Hungarian mountains in the course of the interglacial phases, represented a plastic horizon, an excellent surface of parting for the solifluction arising in the next glacial phase. Broadly speaking, the Hungarian Mountains constituted an area of denudation in the course of the Quaternary; only a thin and mostly eluvial-deluvial, more seldom aeolian-fluvial sedimentary cover was preserved in their area.

Detailed investigations have proved in various ways that the formation of the valleys dissecting the Hungarian Mountains and the foothill areas first began at the Pliocene-Pleistocene limit. Up to the end of the upper Pliocene, the evolution of peneplanes and piedmont surfaces was the predominant

process. In the mountainous areas there existed from the upper Pannonian to the early Pleistocene a drainage pattern of gentle grade and capriciously changing course in broad, flat straths. The streams incised themselves only in the upper Pleistocene and even later than that in the large basins where the fixation of the drainage pattern in its present form was due to human activity.

2. The Great Hungarian Plains comprising the eastern half of the country constituted a huge basin of accumulation in the entire Quaternary. In the basin a sedimentary series of several hundred metres was deposited, lacustrine and fluvial in the beginning, turning limnic-fluvial-aeolian in the upper Pleistocene between the river beds of the ever-changing drainage pattern (for details see papers by MIHÁLTZ and MOLNÁR). The Little Hungarian Plains situated west and northwest of the Transdanubian Mountains, the immediate area of accumulation of the waste derived from the Alps and the Western Carpathians, was filled in the Quaternary by mostly fluvial deposits (sand and gravel). The maximum thickness of the Quaternary in the Little Plains depression amounts to about 300 metres, whereas in the Great Plains it locally exceeds 1000 metres. It is these features that resulted in the accumulation of a normal, complete stratigraphic record in the basins in the course of the Pleistocene, whatever climatic conditions prevailed in the meantime, and this is why no terraces came to exist in the basin up to the upper Pleistocene (SZÁDECZKY-KARDOSS 1938). Notwithstanding the intense subsidence, the rhythms and types of the physiographic forms and of the deposits bear locally the traces of the climatic oscillations brought about by the glacial and interglacial phases.

3. In the smaller intermontane basins, in the hummocky regions and on the piedmont surfaces, an alternation of denudation and accumulation prevailed in the Pleistocene. The surface of these landscapes is covered mainly by upper Pleistocene loess, loess-like deposits, wind-borne sand, eluvial-deluvial loam (for details see the paper by PÉCSI). Underlying these is a fairly wide-spread older Pleistocene fluvial series of the alluvial-fan type. The Quaternary cover generally overlies a thick series of several hundred or even a thousand metres of poorly compacted Neogene deposits.

The valley pattern of the hummocky regions is likewise Quaternary, late Pleistocene in its majority, broadened by processes of downslope creep and flow. In some regions, however, embryonal derasional valleys showing no trace of stream erosion — the dells — are exclusive (for details see the paper by SZILÁRD).

The processes of deposition of Quaternary aeolian and fluviatile formations on top of the alluvial fans formed in the subsiding basins also resulted in a diversity of peculiar types. The genetic classification and chronologic evaluation of the deposits was first attacked from the side of lithologic and mineralogic analysis.

The manifold events and formations of the Quaternary have, as a matter of course, raised a multitude of involved geochronologic problems whose solution demanded a great deal of ingenuity and hard work and led to some methods of investigation and research specific to the Carpathian Basin.

The widespread series of terrestrial deposits have yielded in a number of instances well-preserved assemblages of molluscs. As shown by the review written by E. KROLOPP (in this volume), these finds constitute valuable stratigraphic and chronologic evidence. The not less abundant Vertebrate material of the terrestrial series led to the establishing of a system of entirely new biostratigraphic concepts for the Pleistocene, based particularly on the classic lower Pleistocene Vertebrate fauna of the Villány Mountains. The study of the related and contemporaneous human cultures ranging from the earliest Palaeolithic to the youngest prehistoric times has furnished some results remarkable even on an international scale. (See the paper by KRETZOI—VÉRTES). The same paper also reports on the results of absolute dating arrived at up to now and on the incorporation of the same into our system of relative chronology.

During the Pleistocene glacials the entire area of the Carpathian basins belonged to the periglacial zone of non-glaciated Europe (and not only the mountains and hummocky regions, as was erroneously believed earlier) (PÉCSI 1961). In the basin surrounded by tall mountains from every side, the rapid alternation of dry, cold continental and cool but relatively humid spells of climate entailed a set of peculiar climatic conditions. The latest developments of comparative research into the climate and physiography of the Carpathian Basin and the adjacent areas have shown the Carpathian Basin to represent a particular facies of periglacial landscape sculpture and sedimentation, a separate regional province within the Quaternary Eurasian periglacial belt.

In the course of the last glaciation the intensely continental spells of climate were often superseded by continental spells substantially moderated by oceanic elements. Besides some biostratigraphic evidence, this is proven by the alternation of aeolian, solifluctional, slope-washed proluvial deposits in the upper Pleistocene profiles of loess and slope deposits. The sequence of several types of flat-tundra phenomena on the alluvial fans and terraces likewise confirms the above statement. Gravel polygons of barrel size are seen to be dissected by networks of huge frost wedges; these and the traces of ground-ice laccoliths indicate a freeze-and-thaw process reaching down in some phases as far as five metres, whereas some cryoturbated forms occurring in the same exposure may indicate an active soil layer not more than one metre deep.

The substantial changes of the relief, the rapidly alternating climatic phases of varied degrees of continentality and the varying distance from the great continental ice sheet exerted a most profound influence on the biogeo-

graphic features of the region. As a result, the Carpathian Basin, still belonging to a sub-Himalayan humid-Mediterranean forest-type biogeographical zone extending from South-East India to South England in the Late Pliocene (Csarnótan) became by the Earliest Pleistocene an area of invasion of North American faunal elements characterized by a warm-dry steppe-type milieu (Villányian), representing at the same time the western frontier of the extension of some special East European elements (Camelids, Struthionids). Towards the end of this phase, the influence of the first glaciation was already felt, as far as the southern frontier of the country (Villány mountains). In the Lower Pleistocene the position of the Carpathian Basin in thepattern of climatic zones drew besides some further North American elements, also numerous species from Inner Asia and the north (Biharian).

From this time on the relief, not differing substantially from that of today, constituted a barrier isolating the Carpathian Basin from the great Eastern biogeographic zone. As a result, the changes in the faunal and floral assemblages reached the basin in devious ways, partly from the north and partly from the west. In the two upper stages of the Pleistocene (Oldenburgian, Utrechtian) the faunal remains of this country indicate a relatively humid, partly deciduous-forest milieu isolated from the east, belonging to a zonal unit parallel to the margin of the continental ice sheet from England to the Danube Basin. The links of Hungary are, however, stronger towards the likeweise marginal English area than towards the Central European-French region, which had more pronounced continental affinities. The continental elements, which prefer a grassy steppe, result here exclusively from a Central European infiltration. Even so the markedly continental phases in the Carpathian Basin are characterized by low temperatures (the July maxima not exceeding 12 degrees centigrade) and by the association of taiga and tundra elements in the floral and faunal assemblage.

On the other hand, the warming up at the Pleistocene-Holocene boundary was a consequence of the recession of the continental ice into a considerable distance, partly influenced by the somewhat anormal course of the end of the last glaciation.

It is the complex of the above-enumerated circumstances that determines the particular problems of Hungarian Pleistocene research and that offers ways and means of progress in the solution of these problems.

О СВОЕОБРАЗИИ ЧЕТВЕРТИЧНЫХ ОТЛОЖЕНИЙ ВЕНГРИИ

М. КРЕЦОИ—М. ПЕЧИ

Р е з ю м е

На территории Венгрии геологическая история четвертичного периода — в связи с положением внутри Карпатской цепи и со сложными тектоническими событиями — существенно отличается от того, что вытекало бы из зонального положения.

Сами четвертичные образования располагаются в 3 крупных региональных единицах, что обусловлено обстановкой созданной неотектоникой.

1. Среднегорные массивы, поднявшиеся в плейстоценовое время, с невыдержанным, маломощным покровом плейстоценовых отложений и со следами площадных эффектов оледенений.

2. Четвертичный осадочный покров Большой Венгерской Низменности мощностью свыше 1000 м в восточной половине и северо-западном уголке страны.

3. Толща лессов и суглинков, покрывающая холмистые районы западной половины страны и краевые зоны среднегорий.

В четвертичный период на территории Венгрии формировалась своеобразная перигляциальная фация с меняющимися континентальными и океаническими фазами, причем вначале осуществлялось прямое биогеографическое сообщение с востоком, а позже с западом.

SOME OBSERVATIONS CONCERNING THE QUATERNARY SEDIMENTATION IN HUNGARY

By

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Extensive research on the loess cover of the hills and mountains of Hungary and into the deposits filling the Quaternary basins has brought forth a number of interesting results. The basin fillings reveal a well-defined rhythm of fluvial deposition. The fluvial series with a thickness varying between 200 and 600 metres have yielded some evidence highly useful in the chronological subdivision and reconstruction of the geological history of the Hungarian Quaternary.

From the geological point of view the study of the loess types of the mountains, hills and plains has led to the distinction of the following four loess varieties: typical loess, slope loess, the loess of the alluvial fans in the plains and the loess of the deep-lying floodplains, likewise in the plains. The distinction of these varieties is based not so much on the grain size distribution and mineralogical composition as on structural and textural features and the state of diagenesis of the constituent minerals.

In certain regions of Hungary a regular relation between the altitude and the nature of the slope deposits could be established.

The study of the manifold non-glacial Quaternary deposits of Hungary, initiated by agrogeologists, was continued later on by geologists and geographers. The study of the evolution of the Quaternary basins, the derivation of the sediments and the cycles of sedimentation, has been initiated in 1964 after the detailed and complex geological and geophysical, survey of the Hungarian Plains. In 1961 the author has published a comprehensive review based on the results of the said survey and the detailed examination of the deposits in the laboratory. The Quaternary of Hungary can be classified in two groups: 1. the basin sediments filling the deep Quaternary depressions, 2. the sedimentary cover of the mountains and elevated plateaux.

The deep Quaternary basins occupy nearly one third of the country and the thickness of the largely fluvial deposits accumulated in them locally attains 600 metres. With some exceptions of small areas, the mountains and the hummocky regions are almost entirely covered by a Quaternary series, first of all by loess and to a lesser degree by fluvial and deluvial deposits. The thickness of the aeolian cover attains as much as 40 metres. The deposits filling the valleys and constituting the terraces, vary from a few metres to a few tens of metres in thickness, seldom exceeding a hundred metres (Fig. 1).

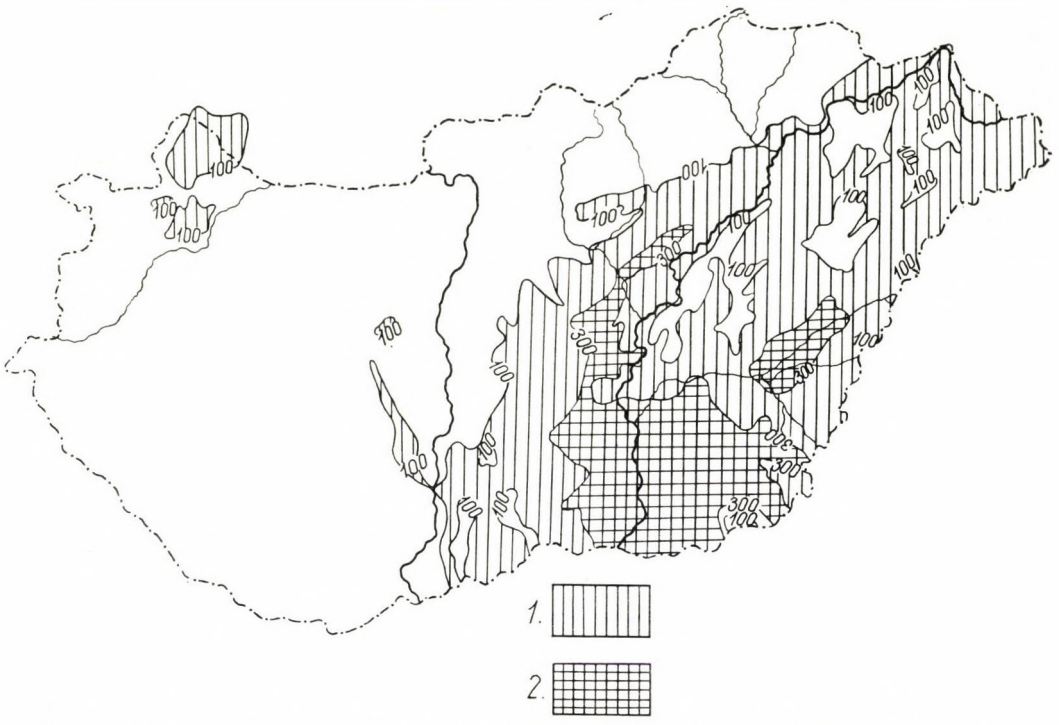

Fig. 1. Deep basins of the Quaternary: 1. — Quaternary deposits thicker than 100 metres, 2. — Quaternary deposits thicker than 300 metres

I. The Quaternary series of the basins

The thick sedimentary sequence of the deep Tertiary basins is mostly overlain by Quaternary fluvial formations. The deposition of these latter was a rhythmic process, owing to the stepwise subsidence of the floor of the basin. The fluvial series consequently exhibits a vertical sequence of graded deposits, coarse at the bottom, gradually becoming finer upwards (RÓNAI 1960, URBANCSEK 1963).

The above-mentioned cycles of deposition, each comprising 50 to 100 metres of sediments, reflect the stepwise sinking of the basin floor, whereas the small-scale variations of the grain size distribution are considered to be due to climatic oscillations and to the shifts of the drainage pattern. A sudden local subsidence is invariably indicated by the abrupt coarsening of the deposits which is succeeded by a single process of grading into finer deposits. The climatical oscillations resulted in a similar but not entirely identical phenomena (Fig. 2).

In the last few years over thousand borehole logs have been recorded in holes drilled for hydrocarbons and water. In case the series is poorly compacted,

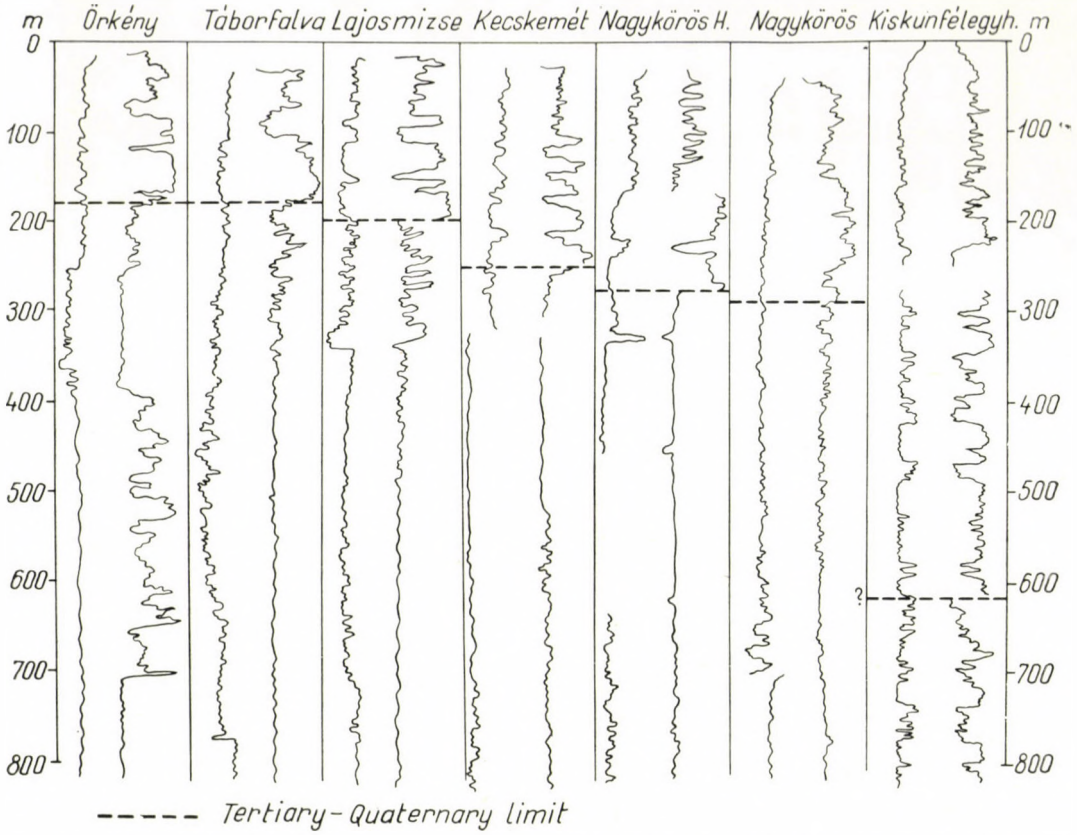

Fig. 2. Some characteristic Quaternary well logs. The Quaternary is characterized by greater porosity and higher electric resistivity. The transition to the more clayey and better compacted Tertiary deposits is rather abrupt in most wells. The periodicity of Quaternary deposition is readily observed on the logs

the electric resistivity logging is well suited to distinguish the coarse-grained deposits from the fine-grained ones. The comparative evaluation of the results so obtained offers a comprehensive image of the facies and of the rhythms of deposition of the Pleistocene. In most instances there is a marked change in lithology at the interface of the Pleistocene fluvial deposits on the one hand and the lacustrine upper Pliocene or upper Pannonian, on the other. The physical parameters have been found to be excellent lithologic indicators whereas the lithologic sequence is indicative of the trends in deposition and — if evaluated jointly with data from other sources — furnishes a useful tool also for the chronologic evaluation of the deposits.

In the interglacials the increased discharge of the rivers resulted in a simultaneous increase of the volume and of the coarseness of the load transported. The resulting coarse deposits can be traced near the ancient base level

of erosion. At the same time, however, also the areas of the floodplains were considerably augmented, a circumstance that resulted in the covering of vast surfaces by fine-grained floodplain silt.

Detailed examination of the deposits in the laboratory has revealed the basin of the Great Plains to be characterized by a remarkable abundance of the silty fraction (0.01 to 0.06 mm) as well as by its high degree of uniformity over large areas. Some of the deposits containing a great deal of silt are considered to be aeolian in origin, but their majority represent floodplain deposits formed in the last stages of the filling of slowly sinking areas. Also in the Danube valley, the final stage of the filling of the basin in the early Holocene brought about the deposition of silty sediments still present in the areas not attained by the late Holocene incision of the river. The finer fractions (mud, clay) were mostly deposited in periodic or permanent lakes or pools. However, the stagnant waters also deposited some silty material, as has been revealed by the grain size study of the middle and upper Pliocene lacustrine sediments. In the glacial phases the load carried by the rivers became less, while aeolian deposition became intense: wind-borne sand and loess were deposited (Fig. 3).

The areal distribution of the above-mentioned types of deposits exhibits the following regularities: in the depressions of the unevenly subsided Tertiary surface the interglacials brought about the deposition of fluvial sediments. On the elevations in between the depressions, no sedimentation occurred: instead they underwent large-scale denudation. The river-laid detritus tended to smoothen out the differences in level. In the glacials, the wind stirred up the sand and silt accumulated in the interglacials and carried it up the flanks of the watersheds. During these phases, sculpture rather than levelling of the relief was the predominant process. In the subsequent interglacial the processes of denudation of the elevations covered with aeolian deposits and that of deposition in the depressions set in with renewed vigour (MOLNÁR 1961).

As a result of the conditions described above, the deep Quaternary depressions contain fluvial and floodplain deposits in the first place, whereas the elevated areas between the depressions are covered with wind-borne sand consisting of intensely worn grains and also with altered loess. Complications are introduced by the fact that the climatic events of the Pleistocene were accompanied by tectonic movements and so the original position of the strata cannot be ascertained with full certainty.

It is rather hard to distinguish the aeolian and fluvial deposits of the basin from each other. Besides the intense wear of the grains the wind-blown sand is characterized also by its excellent sorting. In the typical aeolian sand of the Great Plains, the 0.1 to 0.2 mm grain size fraction constitutes up to 80 percent of the sediment. There are, as a matter of fact, layers of fluvial sand equally well sorted, which can, however, be distinguished on the basis of a secondary peak of the grain size distribution curve, as established by SZÁDECZKY-

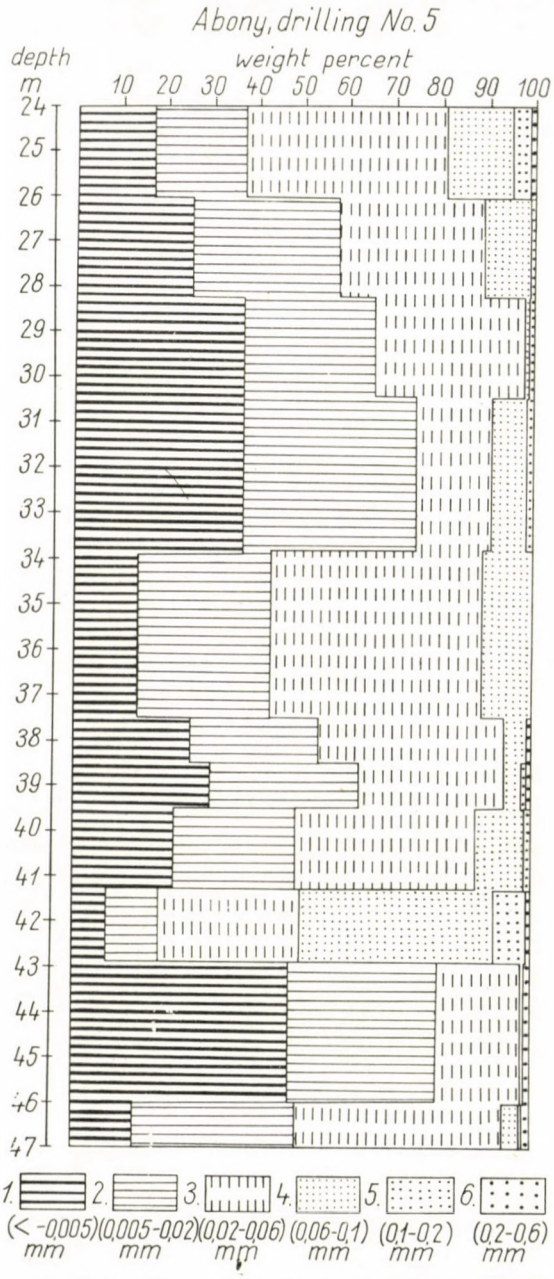

Fig. 3. **Weight percentual abundance of the silt fraction in the drilled wells of the Great Hungarian Plains. Similar grain size distributions have been observed throughout considerable depth intervals in a large number of wells in the Plains. 1. — clay, 2. — mud, 3. — silt, 4. — superfine sand, 5. — fine sand, 6. — medium sand**

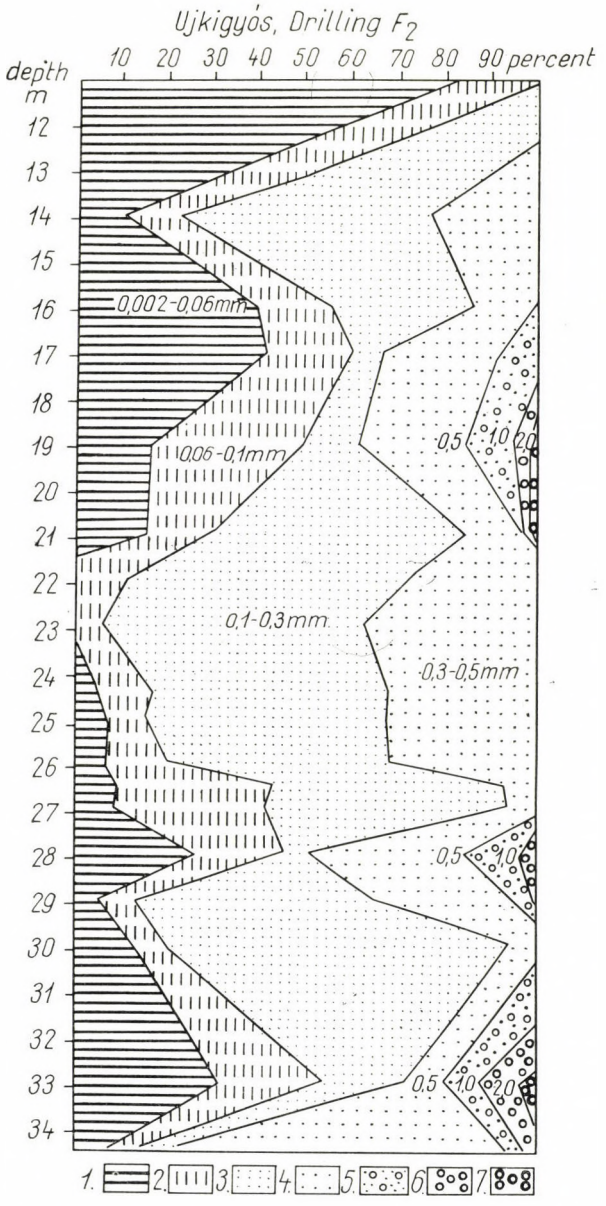

Fig. 4. Characteristic grain size distribution of a fluvial series of deposits. The characteristic feature is the abrupt variation within rather broad limits of the granulometry. 1. — Clay, mud and silt fraction, 2. — Superfine sand, 3. — Fine sand, 4. — Medium sand, 5. — Coarse sand, 6. — Fine gravel, 7. — Gravel

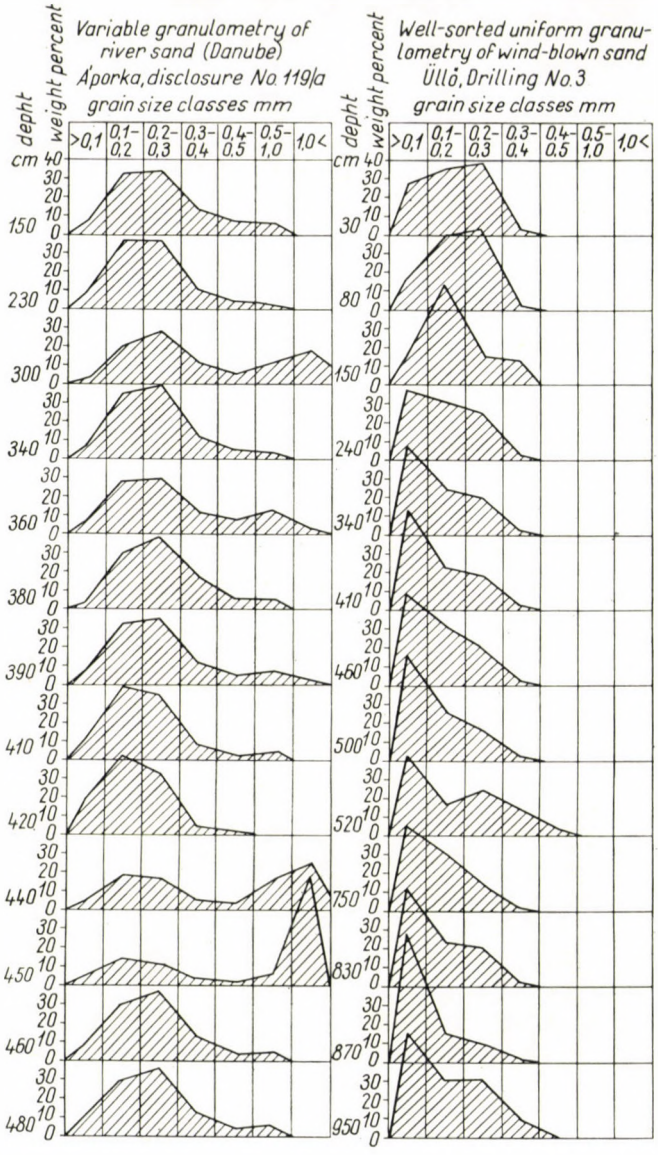

Fig. 5. Comparison between the grain size distribution of river-laid and wind-borne sand. The river-laid sand is less thoroughly sorted and is of variable grain size. The wind-borne sand is excellently sorted and is of a uniform grain size

KARDOSS in 1938. On the other hand, the fluvial deposits exhibit rather a rapid alternation of layers and corresponding shifts in the grain size distribution, owing to the nature of the fluvial sedimentation and to the pulsating supply of the load borne by the rivers (UNGÁR 1960, RÓNAI 1963, FRANYÓ 1964), (Fig. 4—5).

It is even harder to distinguish the coarse-grained varieties of fluvial mud from compacted loess if the latter is diagenized by ground water and by the pressure of the overburden. Both can be slightly plastic and of remarkably similar grain size distribution. In this case, too, the presence of homogeneous layers of some thickness is an argument in favour of an aeolian origin. Under especially favourable circumstances, gastropod finds may help to establish the difference. From the practical point of view the correct judgement of the origin of the deposits is of a certain importance in the parallelization of the layers between deep wells, in the extrapolation of the data of research borings and in estimating ground water reserves (MOLDVAY 1961, HORVÁTH 1963—1964).

In the course of the evaluation of drill logs, clayey formations occurring in a somewhat puzzling manner in the form of caps over slightly vaulted formations rather than on the bottom of the depressions, are sometimes encountered. One reason for this may be a crustal movement subsequent to deposition; however, some of the deposits classified as "clays" in the well logs may as well be deposits of aeolian dust settled on top of the elevated parts, which was not affected by the streams of the contemporary relief (Fig. 6).

In the fluvial, deluvial-colluvial and aeolian series of the basin, true clays are relatively scarce. In the periodic pools, in the dammed-off waterlogged floodplains of considerable area, or in periodical or perennial marshes and swamps, clays or related deposits may nevertheless have developed. The plasticity of these latter is due in the first place to the organic matter present in them (turfy and mucky clay types, swamp and marsh clays) or secondly to the action of basic salts (alkali clays). The clay mineral of these deposits is almost invariably of the illitic type.

The deluvial-colluvial-eluvial deposits of the basin can be distinguished by their grain size distribution which exhibits several maxima (clayey gravel) or by their particular lithologic features (colour, fissuration), or by their humus content. Slope clays and red clays washed in from the marginal parts of the basin are encountered fairly often at considerable depth. These terrestrial clays, occurring at great depths in the Quaternary basins, might have been derived from the Tertiary hills covered today by younger deposits, as well as from the Recent piedmonts of the mountains. From the practical point of view one of the most important properties of these washed-in slope clays and red clays is their mixed grain size and fissuration which considerably increase the permeability. As a result, some of these clay layers, when intensely fissured, may become fair aquifers. The mixed grain size distribution and the fissuration can be atrributed to freeze-and-thaw and solifluction phenomena of the cold phases of the Quaternary (Fig. 7).

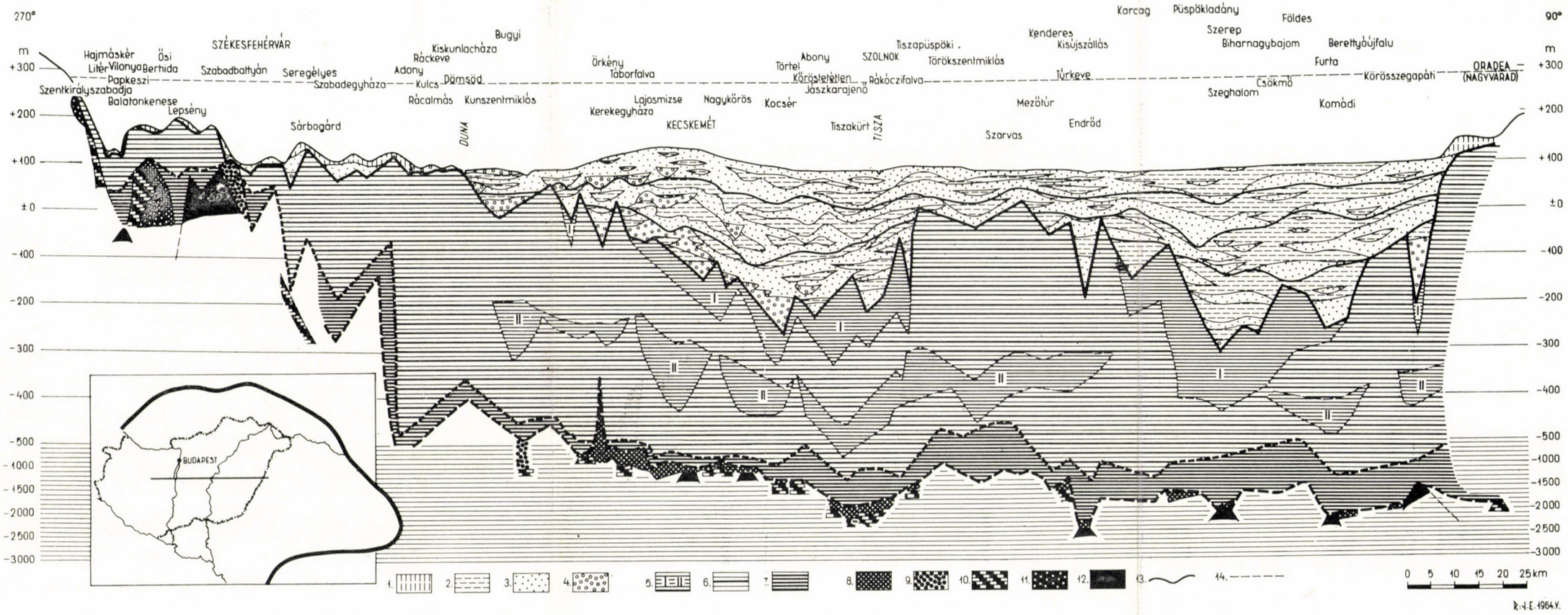

Fig. 6. Geological profile across the Hungarian Plains between the Bakony and Bihar Mountains 1—4. — Quarternary deposits, 1. — Loess, 2. — Fluvial clay and mud, 3. — Sand, 4. — Gravel, 5. — Upper Pliocene (I) and upper Pleistocene (II) clay, 6. — Rapid alternation of upper Pannonian clay and sand beds, 7. — Lower Pannonian deposits, 8. — Neogene volcanics, 9. — Palaeogene deposits, 10. — Mesozoic basement, 11. — Permian, 12. — Palaeozoic crystalline basement, 13. — Limits of the cycles of Quaternary deposition, 14. — Schematic trace of the profile. The names of villages symbolize the localities of the borehole logs which have been incorporated in the profile. Their distance from the schematic trace indicates their true distance from the profile line, according to the horizontal scale of the profile. Below — 500 metres the vertical scale is reduced five times. This was the only way of presenting also the relief of the basement

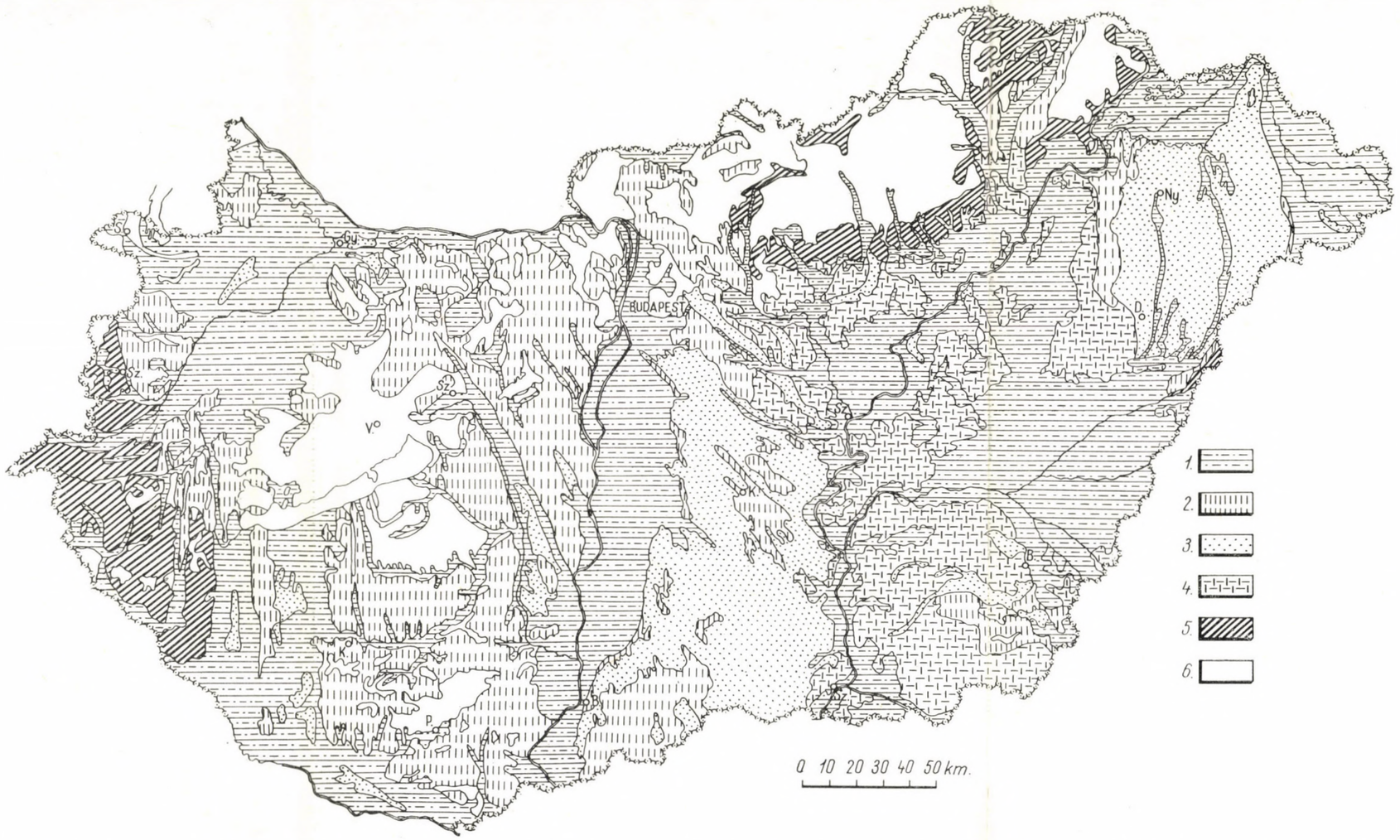

Fig. 7. Generalized map of the Hungarian Quaternary deposits 1. — Fluvial deposits, 2. — Loess, 3. — Wind-borne sand, 4. — Muddy loess of the depressions (hydroaerolite), 5. — Slope clays, 6. — Pre-Quaternary formations

II. The Quaternary cover of the mountainous regions and of the plateaux

As far as the thin Quaternary series covering the hills and mountains and part of the basins are concerned, research has lately been directed in the first place to the deposits of aeolian and deluvial-colluvial origin included in these series (PÉCSI 1962).

1. The surface of the regions as mentioned above is covered to a considerable extent by aeolian deposits mostly consisting of loess and loess-like deposits and of wind-borne sand to some extent.

In Hungary besides the young redeposited loess-silt that was washed off the early Holocene relief of the mountains, it is customary to distinguish four fundamental types of loess:

a) Typical loess,

b) Slope loess,

c) The loess of the vast alluvial fans of the plains, the so-called Alföld loess,

d) The floodplain loess of the waterlogged parts of the basin.

1/*a*. The typical loess of the mountains and hills is uniform over large areas. With a thickness of 10 to 20, exceptionally of 40 metres, it is invariably interrupted by layers of sand or by horizons of loess, the latter being altered into loam or soil. The thickness of the homogeneous packs of loess intercalated between the sand and fossil soil horizons, does not as a rule exceed 4 to 6 metres. The intercalated sand layers mostly consist of worn wind-borne grains (Fig. 8).

Of the several fossil soil horizons present in the typical Hungarian loess profiles, two loamy horizons are persistent over most of the area. As a rule, both consist of two sub-horizons which indicate that soil genesis was not uninterrupted even in the periods of mild climate. In other words, longer spells of a mild climate coupled with rich precipitation (the interglacials) were modulated by cold spells just as the cold glacial phases were interrupted by mild spells (the interstadials) which is an obvious result of the solar control of the climatic oscillations during the Ice Age. On the valley slopes and in the piedmont areas the soil horizons are observed to split in two or several sub-horizons, indicating repeated erosion and redeposition of the layers. In certain loess profiles the two well-developed and mostly bipartite soil horizons are accompanied by a third one, generally constituting the lowermost horizon in some exceptionally thick loess profiles, presumably on the Tertiary-Quaternary interface. The loess packs in between the fossil soil horizons present a homogeneous aspect confirmed by a uniform grain size distribution and chemical composition, except for a slight downward increase of the lime content in some instances (RÓNAI 1964).

Some of the results of the thorough examination of the loess bluff of Kulcs (50 km south of Budapest on the right bank of the Danube) are presented in Fig. 9.

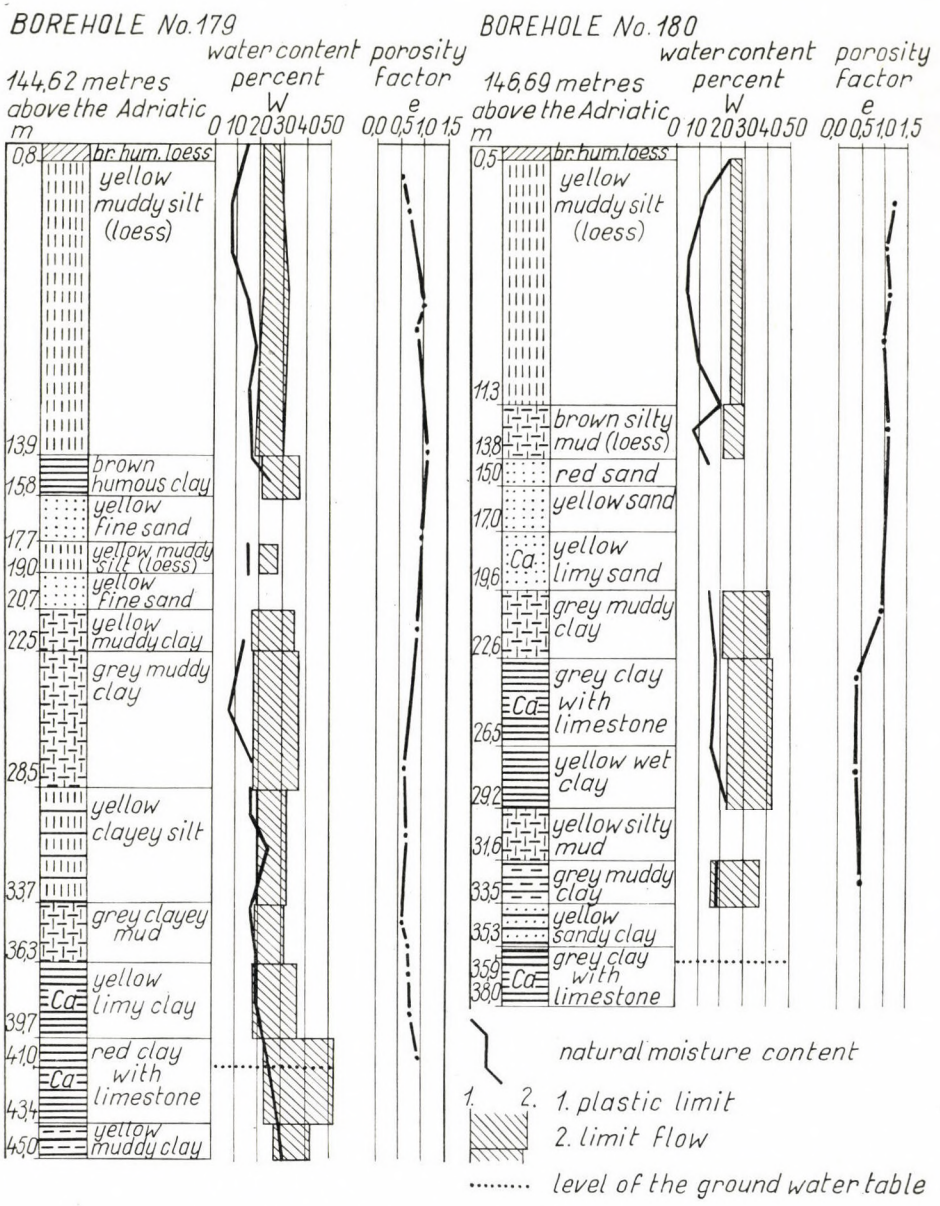

Fig. 8. Borehole logs of the loess profile at Dunaújváros

Although several loess profiles of 20 to 40 metres thickness have been subjected to detailed studies, the evidence accumulated is as yet insufficient to warrant a chronological subdivision of the sedimentary record.

Even on a country-wide scale the grain size distribution and chemical composition of the typical loess is highly uniform. The results of chemical

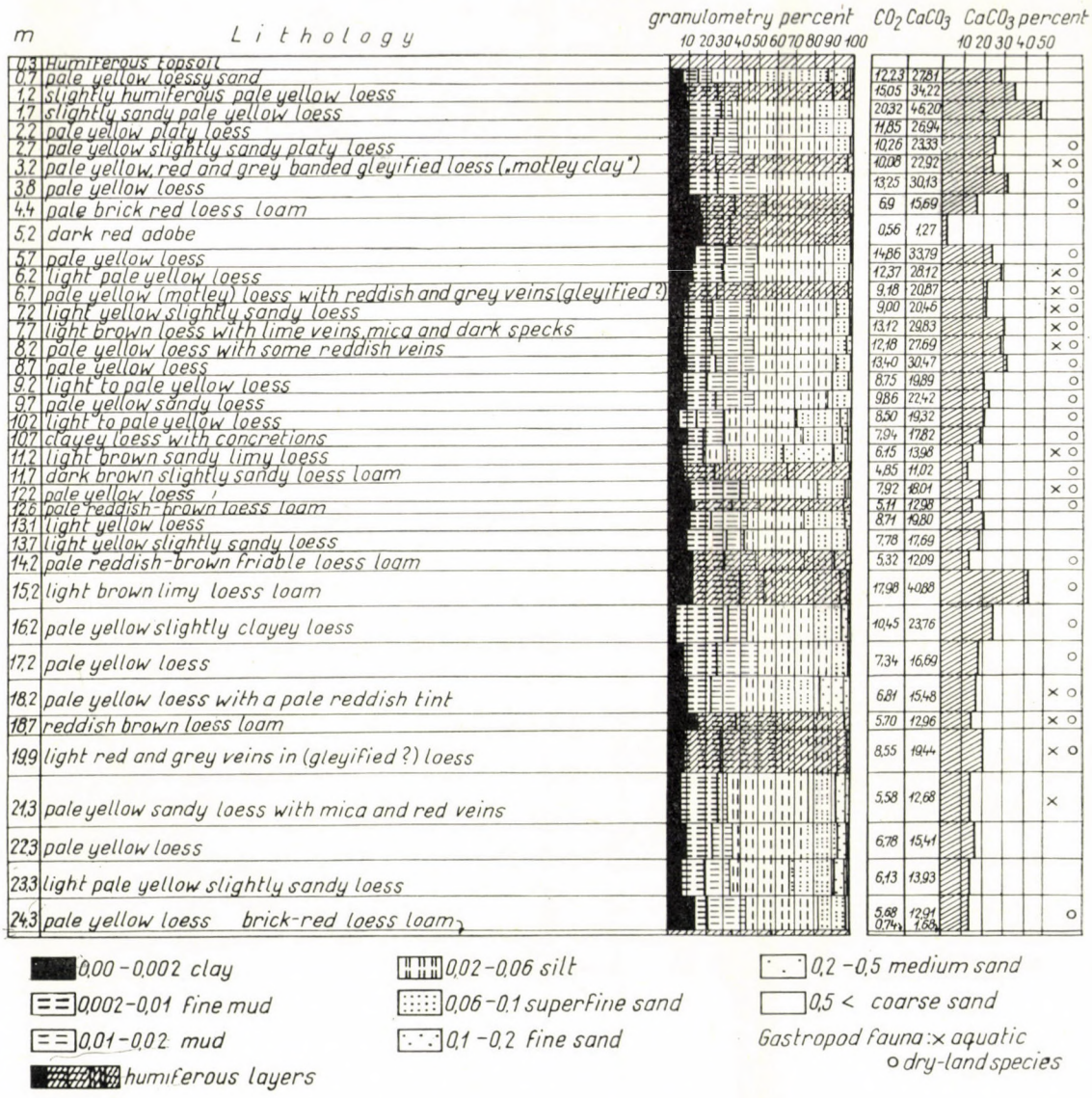

Fig. 9. **Profile of the loess bluff of Kulcs. 1962.**

analysis offer, however, no inferences as to the age, the nearby or faraway source of the dust, the conditions and the medium of its deposition. In the degree of diagenesis of the sediment and in its microscopic structure there are, however, certain differences.

The chemical analyses of several hundreds of Hungarian loess samples have furnished the following extremal values of the constituents:

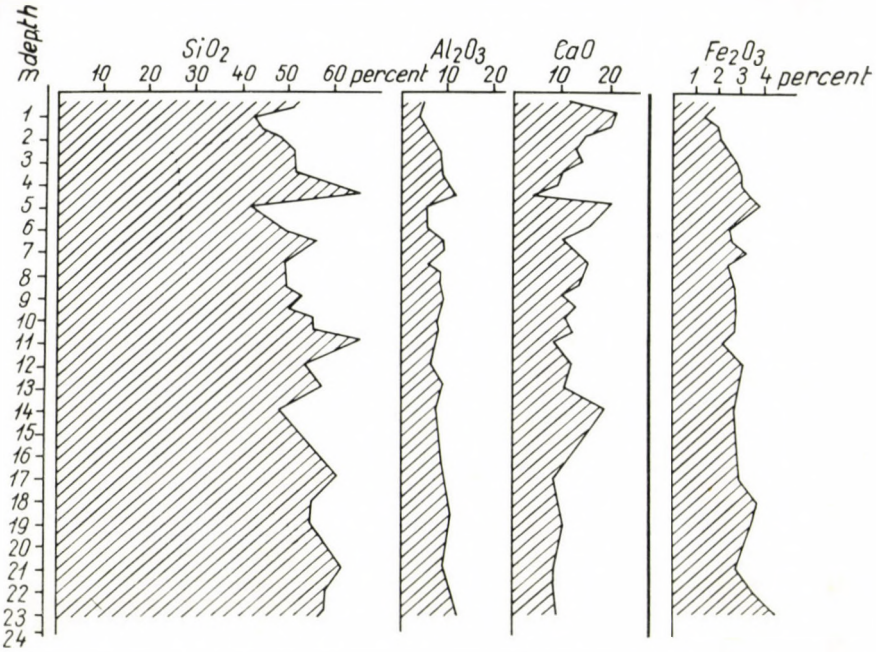

Fig. 10. Some details of the results of chemical analysis of the loess bluff of Kulcs (Analysts, Mrs P. MIHÁLYI and Mrs I. SOHA)

Chemical composition of the loess samples
Extremal abundances

SiO_2	41.2	to	74.9	weight percent
Al_2O_3	5.0	to	17.3	weight percent
CaO	0.7	to	24.3	weight percent
MgO	1.0	to	8.1	weight percent
Fe_2O_3	1.3	to	5.5	weight percent
FeO	0.5	to	2.7	weight percent
K_2O	0.8	to	2.9	weight percent
Na_2O	0.6	to	1.6	weight percent
TiO_2	0.2	to	1.2	weight percent
MnO	0.1	to	1.0	weight percent

The fact that the variations in composition are just as large from one end of a given loess profile to the other as those between the various regions of the country, suggests that the differences are due to local factors acting on a very small scale (Fig. 10).

Undoubtedly, the weight percentages of the individual chemical components are influenced to a considerable degree by the variations of the calcium carbonate content, a parameter that also reflects local conditions. If, however, the calcium carbonate content is removed by treatment with hydrochloric acid, there is still a considerable scatter of the abundance of the chemical components, no areal regularity of the scatter can be discovered.

In the grain size distribution of typical Hungarian loess, the dust fraction of 0.02 to 0.06 mm size constitutes 45 to 55 percent, the rest consisting of finer and coarser grains in about equal proportions. In some regions, more sandy varieties of loess occur, that cannot, however, be classified as sand. In Hungary sandy loess is consequently considered to be a subtype of typical loess.

1/*b*. Typical loess occurring in its original site of deposition is restricted to the flat plateaux on the smooth surface of the Pannonian tablelands. The loess originally deposited in regions of a more marked relief, is usually reworked and redeposited, sometimes mixed with the material of the underlying layers. The peculiar stratification, the presence of strings of sand and gravel in the profile and the leached aspect of the valley and slope loesses is a phenomenon long known to Hungarian workers. Over fairly large areas recent research has demonstrated the reworked structure and the fine stratification of the loesses.

Also belonging to the category of slope loesses are the types of loess occurring in hummocky regions where the deposition of loess was accompanied and succeeded by processes of soil genesis under the late Pleistocene and the Recent climate rich in precipitations. As a result, the entire loess profile is leached and decalcified and is of an intense brown colour, but still retaining its characteristic loessy aspect. The loess cover of the Alpine foothills on the western frontier of Hungary is of this type.

1/*c*. The loess of the vast Pleistocene alluvial fans is distributed in strips and spots between dunes of sand. Its thickness, a few tens of centimetres as a rule, nowhere exceeds a few metres; it occurs generally in spots that are a couple of kilometres long and a few hundred metres wide. The grain size distribution reminds of that of typical loess, the sand fraction sometimes being slightly enriched.

1/*d*. A slightly more compacted loess type (vaguely stratified locally), slightly enriched in mud and clay is encountered over extensive areas in the deepest parts of the Great Plains. The thickness of this rather uniformly developed type of loess does not exceed a few metres either, but it may cover spots of several kilometres diameter. It is considered to be a deposit of aeolian dust fallen on a waterlogged surface, designated as "hydroaerolite" on the geological maps of Hungary. The term is due to A. FÖLDVÁRI. It has been also variously called water loess, swamp loess, infused loess, etc. Its surface is likely to bear alkali soils. The mean elevation of the Great Plains above the Adriatic

is 100 metres, that of its deepest parts being 80 to 85 metres. Hydroaerolites occur as a rule on surfaces under 90 metres.

2. Besides loess, the most widespread formations in the mountains and hills are a variety of slope deposits. A common feature of these is the fact that they include mixed Quaternary and older formations of diverse origin. In the course of their continual or intermittent movement downslope the basic mixture of the afore-mentioned substances underwent some subsequent modifications by frost phenomena and pedogenic process that mobilized and redistributed the iron and lime compounds even within the deposit itself.

One group of slope deposits consists of coarse rock detritus-boulders, gravel, sand, and mixtures of these in varying proportions in a clayey matrix. Deposits of this kind represent the comminuted scree and gravel cloaks of the peneplanes, the debris of the alluvial fans, of rockflows, boulder fields, etc. Another group of slope deposits consists of fine-grained clayey substances, partly washed out of the finer-grained underlying deposits, partly laid down by the wind in the form of dust, and partly contributed by the decomposition of massive rocks.

The Hungarian valleys were mostly scooped out in the Quaternary and their filling is Quaternary as well. In the course of the Pleistocene, the Hungarian mountains underwent an uplift of considerable magnitude. Some of the fault blocks were uplifted continuously or in a single step, whereas others emerged in a rhythmical series of movements. In the case of the former it is rather hard to determine the age of the slope deposits, whereas in the latter the terraces and the stepwise arranged piedmont surfaces may indicate the outlines of a chronology (PÉCSI 1963).

The evolution of some of these slope deposits began as early as in the Tertiary. Thus for instance the decomposed layer covering the Tertiary volcanics of this country already moved a certain distance down the steeper slopes prior to the frosty spells of the Quaternary, accumulating in favourable spots in the form of distinct depositional units. In the course of the Quaternary, however, all these deposits underwent further substantial changes.

Just like the terraces, the coarse detritic slope deposits are classified according to their altitude, or grouped together without further chronologic classification into a comprehensive Quaternary group. The chronology of the pelitic formations, however, can be based on a number of features other than their altitude, such as their leaching and the precipitation of diverse compounds, the colour of the iron compounds in the layer, the lime content and its modes of occurrence (lime dolls, thin layers of fine limy mud, nodes, complete leaching, fine disseminated lime, etc.), their structure and texture, homogeneity or compaction, friability, sandy or gravelly admixtures, etc.

Almost everywhere in Hungary the oldest slope clays are mostly of a deep red to reddish violet colour. They exhibit traces of intense frost action,

fissuration and kneading, due to solifluction. Most of this horizon is eroded except for a few rags and thin layers. At several points it is only the red cement of the older gravel terraces that indicates the presence of the former overlying red clays, removed since (RÓNAI 1961/II).

The colour of the younger slope deposits exhibits a regular variation with the age of the formation becoming first reddish-brown, then brown and

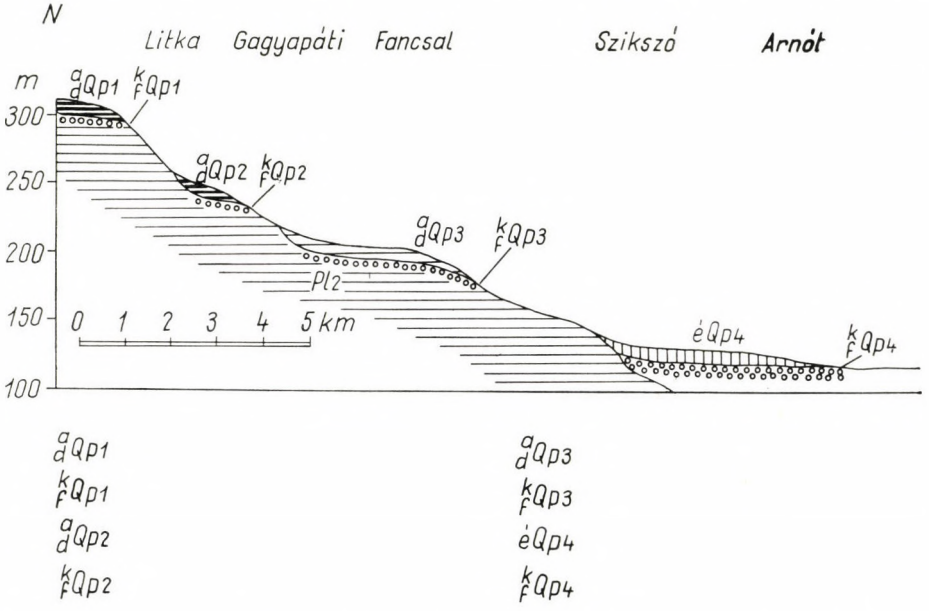

Fig. 11. $^{a}_{d}Q_{p1}$ lowermost Pleistocene red clay, $^{k}_{f}Q_{p1}$ lowermost Pleistocene gravel, $^{a}_{d}Q_{p2}$ lower Pleistocene reddish-brown clay, $^{k}_{f}Q_{p2}$ lower Pleistocene gravel, $^{a}_{d}Q_{p3}$ middle Pleistocene brown clay, $^{k}_{f}Q_{p3}$ middle Pleistocene gravel, $^{l}_{e}Q_{p4}$ upper Pleistocene loess, $^{k}_{f}Q_{p4}$ upper Pleistocene fluvial gravel

finally yellowish brown. The younger deposits tend to be less chaotic, exhibiting the traces of less intense frost action and their structure gradually approaches that of loess as the aeolian dust fraction is not yet diagenized. The youngest member of the slope deposit series, loess, mostly overlies either the older brown and red clays or the lowermost levels of the piedmont steps, slopes and terraces (Fig. 11).

A particular regular development of the slope deposits of various ages is observed on the very gentle southerly slopes of the south-dipping Pannonian table of the Cserehát region (between the Hernád and the Bódva rivers), in NE Hungary.

Besides the above-enumerated deposits, travertines, calcareous tuffs and calcareous muds mostly connected with some kind of hot-spring activity are also fairly widespread in Hungary. Their palaeontological study is under way.

The results of a country-wide geological survey after World War II, have first been published in the form of a map of 1 : 300,000 scale. Since 1962 the Hungarian State Geological Institute successively publishes 1 : 200,000 scale map sheets covering the country, each publication comprising 5 to 6 maps of the area of a given sheet constructed according to various points of view. These maps mostly include a huge volume of information concerning the Quaternary deposits, particularly of the plains.

REFERENCES

(For earlier publications see the Hungarian Report submitted to the Warsaw, 1961, Congress of the INQUA.)

BALOGH, K.—RÓNAI, A. (Editors): The Geological Map of Hungary, 1 : 200,000, Sheet Eger, published by the Hungarian State Geological Institute. 1962. 1. Geological map, 2. Geological map with on the Quaternary removed, 3. Engineering geology map, I—II., 4. Hydrogeologic map, I—II. 5. Economic geology map. — BÁRDOSSY, GY.: Földtani Közlöny **91,** 44—64, 1961. — BIDLÓ, G.: Földtani Közlöny **93,** 244—247, 1963. — FRANYÓ, F.: Földtani Intézet Évi Jelentése 1961-ről, 31—45, 1963. — GÁBORI—CSÁK, V.: Archeológiai Értesítő **87,** 125—129, 1960. — HORVÁTH, A.: Acta Biologica **8, 9, 10,** 173—192, 101—115 and 131—146, 1963—1965. — KRETZOI, M.—VÉRTES, L.: Acta Geologica **8,** 313—318, 1964. — KRIVÁN, P.: Földtani Közlöny **90,** 303—321, 1960. — KRIVÁN, P.: Földtani Közlöny **90,** 56—72, 1960. — KRIVÁN, P.: Földtani Közlöny **94,** 257—265, 1964. — LÁNG, S.: Acta Geologica **8,** 477—486, 1964. — LÁNYI—MIHÁLYI, I.—Mrs. SOHA, I.: Földtani Intézet Évi jelentése 1962-ről, 457—466, 1964. — MOLDVAY, L.: Földtani Közlöny **91,** 292—299, 1961. — MOLDVAY, L.: MTA Dunántúli Tud. Kut. Int. Értekezések 1961—62, 37—76, 1963. — MOLNÁR, B.: Földtani Közlöny **91,** 300—315, 1961. — MOLNÁR, B.: Földtani Közlöny **93,** 97—107, 1963. — MOLNÁR, B.: Hidrológiai Közlöny **44,** 347—355, 1964. — MUCSI, M.: Földtani Közlöny **93,** 373—386, 1963. — PÉCSI, M.: Földtani Közlöny **93,** 195—212, 1963. — PÉCSI, M.: Földrajzi Értesítő **11,** 19—39, 1962. — RAPP—SIK, S.—TOLNAY, V.: Földtani Intézet Évi Jelentése 1962-ről, 467—479, 1964. — RÓNAI, A.: Die Besprechung der ungarischen Quartärsedimente. INQUA 6th International Congress, Warsawa 263—286, 1961. — RÓNAI, A.: Földtani Intézet Évi Jelentése az 1957—58-ról, 165—200, 1961. — RÓNAI, A. (Editors)—MOLDVAY, L.: The Geological Map of Hungary. 1 : 200,000, Sheet Debrecen, published by the Hungarian State Geological Institute 1963. 1. Geological map, 2. Engineering geology map, 3. Hydrogeologic map. I—II., 4. Economic geology map. — RÓNAI, A.: Hidrológiai Közlöny **43,** 130—137, 1963. — RÓNAI, A.: Földtani Intézet Évi Jelentése 1960-ról, 35—57, 1963. — RÓNAI, A.: Földtani Intézet Évi Jelentése 1961-ről, 19—29, 1964. — SZÜCS, L.: Földrajzi Közlemények **8,** (84), 65—75, 1960. — UNGÁR, T.: Agrokémia és Talajtan **9,** 189—200, 1960. — UNGÁR, T.: Építőanyag **13,** 304—308, 1961. — UNGÁR, T.: Acta Univ. Szegediensis. Acta Min.-Petr. **15,** 53—60, 1962. — UNGÁR, T.: Hidrológiai Közlöny **44,** 537—544, 1964. — URBANCSEK, J.: Hidrológiai Közlöny **43,** 392—399, 1963. — VÉRTES, L.: Quartär **12,** 53—105, 1960.

НЕСКОЛЬКО ЗАМЕТОК ПО ЧЕТВЕРТИЧНЫМ ОТЛОЖЕНИЯМ ВЕНГРИИ

А. РОНАИ

Р е з ю м е

Судя по данным широких исследований, проведенных в последние годы по четвертичным отложениям бассейнов Венгрии, а также по лессовым покровам горных и холмистых районов, толщи речных осадков бассейнов отражают четко выраженные ритмы седиментации. Мощности отдельных толщ чаще всего колеблются в пределах 200—600 м. Они оказывают помощь как в расчленении четвертичного периода Венгрии, так и в реконструкции ее геологической истории.

Исследования по лессовым типам горных, холмистых и равнинных областей позволили выделить четыре типа: типичный лесс, осыпной лесс, лессовый покров конусов выносов равнин и лессы низменных пойм Альфёльда. Они могут быть разделены не столько по гранулометрическому и минералогическому составам, а скорее по условиям залегания, по микроструктуре и по минерализации.

В некоторых районах Венгрии развиты закономерные по своей последовательности серии осыпных осадков, обусловленные высотой над уровнем моря.

GEOLOGY OF THE NEAR-SURFACE LAYERS OF THE GREAT PLAINS OF SOUTHERN HUNGARY

By

the late I. MIHÁLTZ

(edited by M. MUCSI)

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The deposition of the sediments of aeolian origin in the Great Hungarian Plains was controlled by climatic oscillations, hence the study of their facies may serve as a basis for their stratigraphic zoning. The sediments were preserved from denudation in the areas and time intervals characterized by the lowest rates of subsidence (the area between the Danube and the Tisza, and the late Pleistocene, respectively).

In the areas of faster subsidence that were filled up by the rivers, deposition took place in cycles governed by repeated crustal movements. Within the cycles the grain size invariably changes from coarse at the bottom to fine at the top. The facial changes of the fluvial deposits are independent of the climatic oscillations of the Pleistocene.

In the course of the Neogene and the Quaternary, the Hungarian Basin underwent a rhythmic subsidence that resulted in the accumulation of a considerable thickness of fluvial and aeolian deposits. The Hungarian area did not undergo glaciation; nevertheless, the ice-covered regions to the north exerted a definite climatic influence upon the conditions of deposition of the Pleistocene series. Loess is the most important climatic indicator of the Great Plains which was repeatedly invaded by periglacial climate. Of the aeolian deposits, loess is the type that was deposited in the course of the glaciations. The uppermost loess deposit has consequently to be considered as the last formation of the Pleistocene.

The region treated in the present paper comprises the southern, larger part of the region between the Danube and the Tisza, and the part south of the Körös rivers of the trans-Tisza region. On the basis of the nature of the Quaternary deposits, the results of their detailed lithologic study and their relief, the region in question can be subdivided into the following larger units: 1. The Danube valley. 2. The low divide between the Danube and Tisza. 3. The Tisza valley. 4. The south-eastern part of the trans-Tisza region.

The tectonic and geologic evolution of our region in the Quaternary is summed up in Fig. 1. On the basis of certain differences in their constitution, we assume the aeolian deposits to be derived from two different sources. The wind-borne sand was rolled by westerly winds from the Danube valley up the divide in the drier spells of the interstadials (P. KRIVÁN), whereas loess was transported in suspension by easterly air currents in the glacials. These

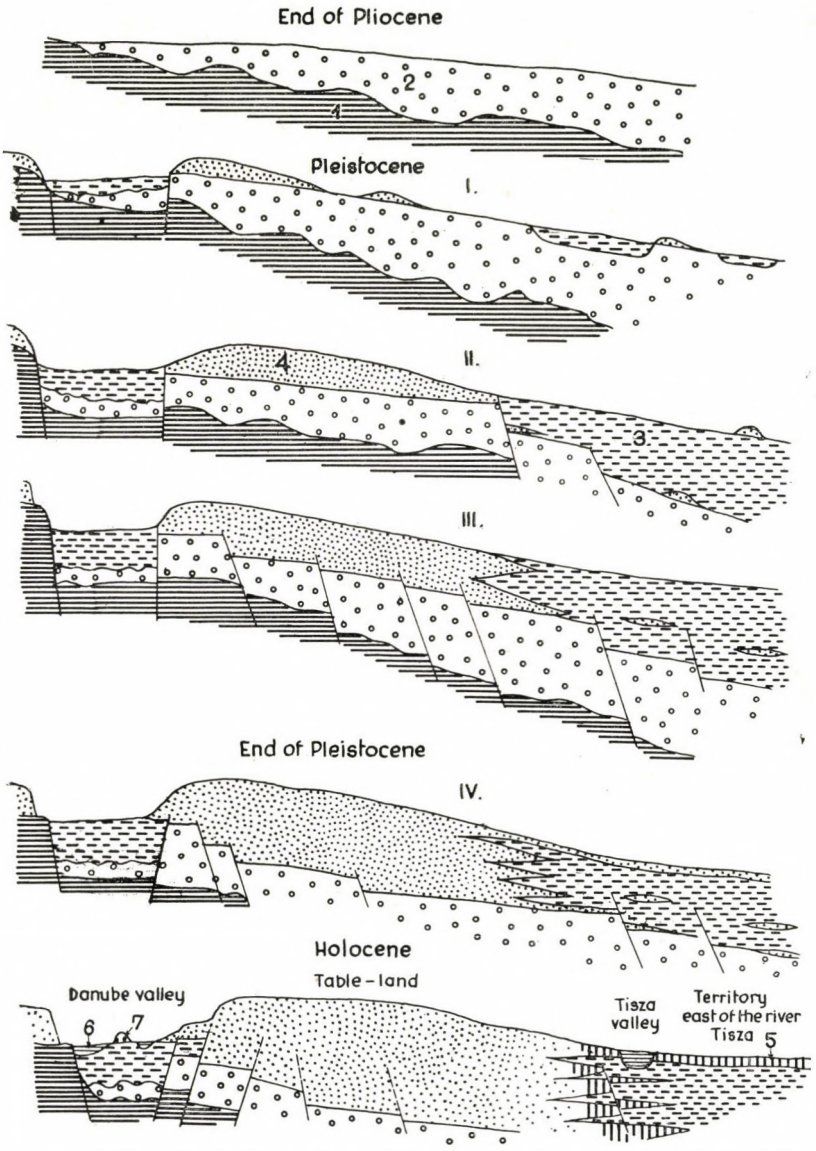


Fig. 1. The geohistorical rhythm of the Quaternary in the Hungarian Plains. 1 — Pliocene (Pannonian), 2 — Pliocene (Levantine), 3 — Pleistocene fluvial, 4 — Pleistocene aeolian deposits, 5 — Pleistocene loess in the Tisza valley and further east, 6 — Holocene fluvial deposits, 7 — Holocene wind-borne sand

deposits were preserved by the relatively slow sinking of the divide in the Pleistocene. In the more rapidly subsiding areas the fraction of aeolian origin got more or less lost in the huge volume of river-laid waste. In the late Pleisto-

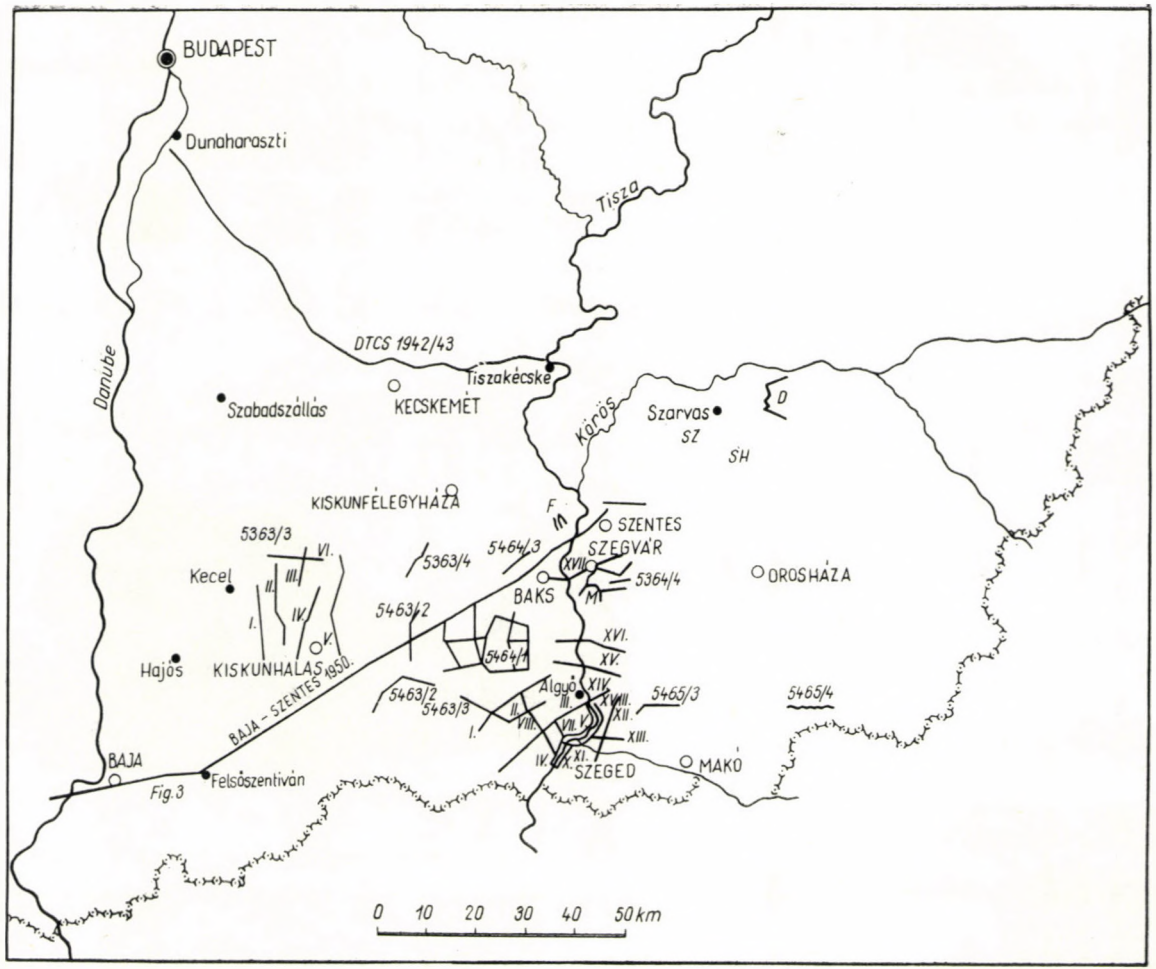


Fig. 2. **Sketch map of the drilling programme executed in the southeastern part of the Hungarian Plains under the author's direction**

cene also the subsidence of the trans-Tisza region slowed down considerably; as a result, a still uncertain number of younger loess layers was preserved in this area, too (Fig. 2).

1. The Danub valley

The valley is a tectonic-erosional depression of 20 to 30 kilometres width. In the south its limits are sharp against the regions to the west and east; in the north, the eastern limit is rather vague. The series of sediments filling the valley is coarse at the bottom, growing finer upwards. Drillings have revealed layers of gravelly coarse sands at 20 to 30 metres depth below the

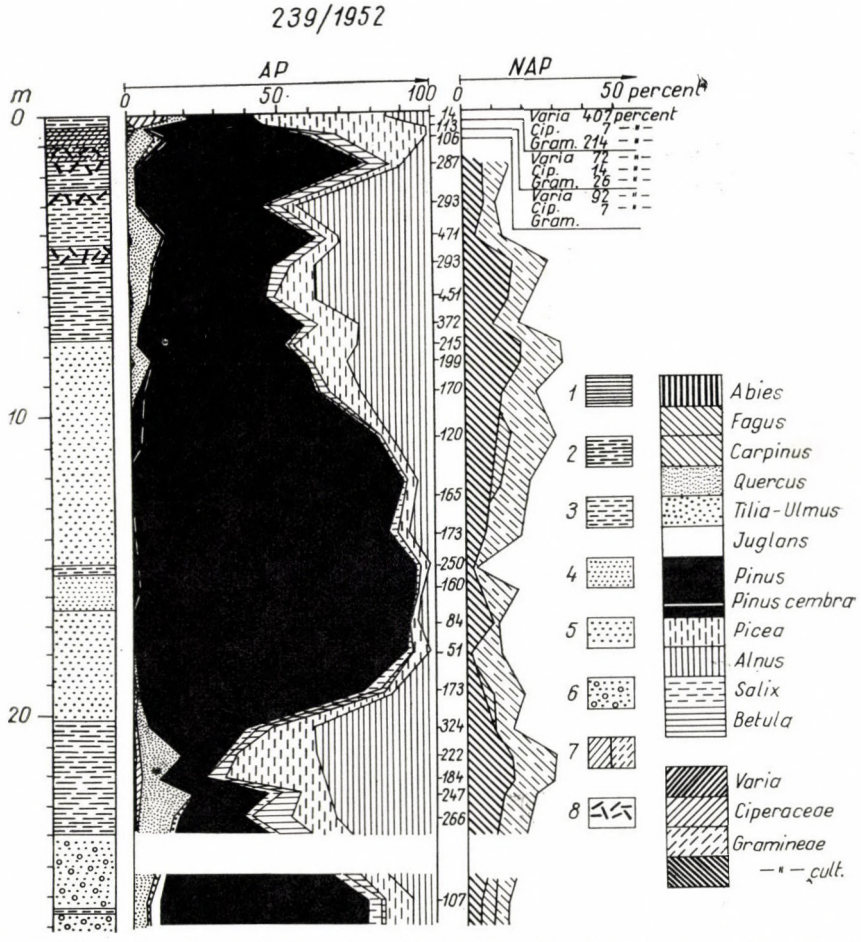


Fig. 3. Well log and palynological record of the drilling No. 239/1950 in the Danube valley. 1 — clay (grain size less than 0.005 mm), 2 — fine silt (0.005—0.02 mm), 3 — coarse silt (0.02—0.06 mm), 4 — fine sand (0.06—0.1 mm), 5 — medium sand (0.2—0.5 mm), 6 — coarse sand (0.5—2 mm), 7 — slightly and intensely humiferous layers, 8 — vegetal remains

surface whose pollen content indicates a deposition in an interstadial phase (Fig. 3).

This gravel is overlain by some 15 metres of medium sand that has exhibited in several borings a characteristic glacial pollen distribution. River beds 10 to 20 metres deep are found incised in the layer of medium sand, filled in their turn with fine sand that grows even finer towards the top of the series. The uppermost layers of the filling of these ancient river beds consist of silt. These layers also reach beyond the river beds and cover considerable areas in a thickness of 1 to 2 metres. The fine sand and silt filling the ancient Danube beds is of Holocene age. In the last glacial phase, the subsidence of the Danube valley slowed down but continued to the end of the Pleistocene. The Holocene beds, however, were incised in the deposits of the last, Würm-3 stadial.

The steep scarp forming the limit of the Danube valley also continues underground. Its existence cannot possibly be explained exclusively on the basis of erosion by the Danube.

The Danube valley is covered in its greatest part by a floodplain silt rich in lime. Owing to its friability this deposit resembles loess, but the grain size distributions of a large number of samples taken from several localities invariably reveal the dominance of the silt fraction over the characteristic loess fraction. The component soluble in hydrochloric acid amounts to 30 to 70 percent; the permeability of the sediment is as low as 10^{-7}—10^{-8} cm/sec. This floodplain silt includes two horizons. Locally as e.g. near the village of Hajós it is seen to surround hummocks of wind-borne Holocene sand. The two horizons of the silt may be separated by a layer of wind-borne sand as e.g. near the village of Gyón. The final stage of the filling of the depressions and derelict river beds is indicated by the formation of turf, most widespread in the neighbourhood of Kecel and Szabadszállás.

2. The divide between the Danube and the Tisza

This region of varied relief overtops the Danube valley by about 30, the alluvia of the Tisza valley by almost 40 metres. Earlier workers (in the lack of sufficient evidence) assumed the divide to be a Pleistocene alluvial fan of the Danube. (TREITZ, BULLA, SÜMEGHY.)

In the course of more than twenty years of detailed investigations, the author and his co-workers have proved the complete absence of river-laid deposits in the whole near-surface series of sediments on the divide, except for some low-lying areas near the rivers. The entire region consists of aeolian deposits (wind-borne sand, loess and their altered varieties).

The deposits in question have been studied in two profiles of borings of 10 to 30 metres depth traversing the entire divide (Fig. 2). The sedimentary

record from several borings (30 to 50 metres depth) around Kecskemét and Kiskunfélegyháza and that from one boring (nearly 80 metres depth) near Felsőszentiván was examined in all possible detail [14, 16, 17]. Finally, the total thickness of the series of aeolian origin has been determined on the basis of numerous artesian wells [36, 47] (Fig. 4).

As a result of all these investigations, the origin and derivation of the aeolian layers between the Danube and Tisza may be conceived as follows:

1. *The spread of layers* of homogeneous lithology in profiles of more than 100 kilometres length is considerable: some of them can be traced through 50 to 80 kilometres. This persistence is a strong argument against the fluvial origin of these layers, as the fluvial deposits tend to occur in wedging-out lenses of considerably smaller extension. Homogeneous deposits of this size must necessarily have been derived from a medium of considerable volume, namely the atmosphere.

2. As to *grain size distribution* both the coarsest fraction (gravel) and the finest one (clay) are absent from the deposits in question.

3. In the fine-grained aeolian deposits the *dominance of the characteristic loess fraction* (0.02 to 0.06 millimetres) could invariably be established. There is hardly any difference in the grain size distribution of several loess samples taken from different depths down to 80 metres. The slight enrichment of the silt and clay fraction in the altered loesses is due to the influence of the vegetation. Even in the case of altered loess (called loam in every-day parlance) the maximum is in the coarse silt fraction (0.02 to 0.06 mm) rather than in the fine silt fraction (0.005 to 0.02 mm, mud fraction in earlier nomenclature).

4. *The colour of the deposits* has long deceived the workers. Below the perennial ground water level the sediments are mostly bluish grey, a fact that made the majority of the workers presume a fluvial origin. This is how the notions of "blue clay" and "blue sand" between the Danube and the Tisza came to exist. The author has proved in several instances that a yellowish loess layer dipping under an increasing thickness of superincumbent layers invariably assumes a bluish colour, first near its bottom and then in its whole thickness. The phenomenon is due to the high concentration of organic matter always present in ground water in the Great Plains which exerts a reducing effect on the deposits. Loesses of this bluish colour were repeatedly found to carry an exclusively terrestrial fauna.

5. *The shape of the sand grains* has been studied on a large number of samples of Recent fluvial deposits and of still moving sand dunes. Both kinds contain sharp angular grains and grains in various stages of wear. The origin of the deposit can be decided in no other way than by determining the percentual distribution of the individual grain shape types [10, 30]. In this way even the origin of sands of wholly unknown derivation can be established to a high degree of certainty. On this basis every sand layer studied in the central,

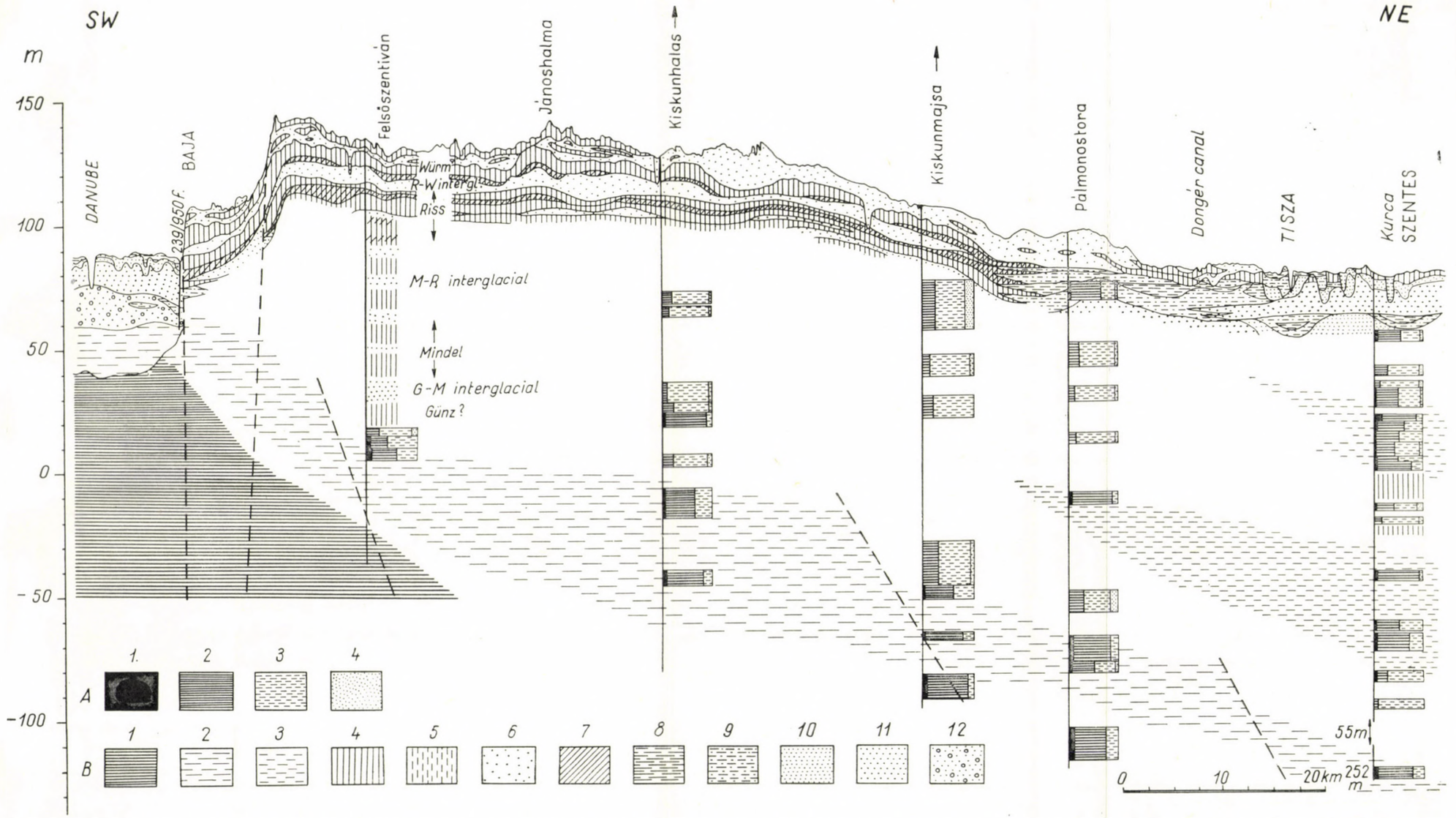


Fig. 4. Transverse profile across the southern part of the divide between the Danube and the Tisza. *A*) Wear of the sand grains: 1 — transparent, glittering splinters, 2 — translucent, slightly rounded form, of worn edges, 3 — slightly frosted form, intensely worn edges, the original shape can still be discerned, 4 — frosted, spherical or oval forms, the original grain shape cannot be inferred any more. *B*) 1 — upper Pliocene (Pannonian), 2 — upper Pliocene (Levantine), 3 — Pleistocene fluvial layers of Tiszian derivation, 4 — Pleistocene loess, 5 — loess-like deposits, presumably reworked locally, 6 — wind-borne sand, 7 — humiferous layers, layers of buried soil, 8 — clay of fluvial origin, 9 — silt, 10 — fine and superfine sand, 11 — medium sand, 12 — coarse sand

elevated part of the region between the Danube and the Tisza as well as the sand washed out of the loess layers was found to be exclusively of an aeolian origin.

6. *The molluscs found in the deposits* offer the most irrefutable evidence as to the deposition of the sediment from a periodic or permanent body of water, or from a stream, or in a floodplain, on a dry or waterlogged surface. The Gastropod remains yielded by more than 100 borings sunk between the Danube and the Tisza have been evaluated by A. HORVÁTH [14, 15, 16]. From the layers that have been determined as aeolian in origin by the lithologic examination, HORVÁTH has described exclusively ubiquitous terrestrial species, mostly of a sparsely wooded habitat as well as some lacustrine species. Several thousand samples assayed as aeolian have not yielded a single fluviatile specimen. (The number of the specimens treated was over 300,000.) On the other hand, both the Danube valley and the lower-lying parts of the divide near the Tisza valley have yielded samples whose lithology reveals a fluvial origin. In these latters HORVÁTH has invariably succeeded in finding fluviatile molluscs.

7. The strings of depressions and small lakes traversing the divide in a general NW–SE trend are considered according to the "alluvial fan theory" as derelict Danube beds. In this case, however, the depressions should contain at least some fluvial sand; at any rate, the sands should be richer in angular grains than those of the elevations separating the chains of depressions. The grain shape analysis of several transverse profiles of close-spaced boreholes has revealed the absence of any such correlation: the depressions have nowhere been found to contain sands of an inferior degree of wear [10].

8. The lithologic study as well as the evaluation of the molluscs and the pollen of the sedimentary record from the 80-metre research well of Felsőszentiván —as completed with the data of a nearby artesian well sunk at the same time — has demonstrated the aeolian deposits to be 124 metres thick at this locality. The Felsőszentiván sequence presumably comprises the entire Pleistocene. Below 124 metres depth, the fluvial deposits have yielded a pollen assemblage of Pliocene traits [34].

9. On the basis of a large number of artesian wells, the total thickness of the aeolian series has been found to exceed 150 metres in the eastern and central part of the southern half of the divide. The wells that have encountered this thick aeolian series are grouped in a zone of N—S strike. Thence the thickness of the aeolian deposits decreases both to the east and west, being interfingered in the area adjacent to the Tisza valley with fluvial layers of Tiszian derivation wedging out towards the central part of the divide. All the above-mentioned deposits are underlain by fluvial strata of Danubian derivation, dipping in the direction of the Tisza valley. These latter are of an upper Pliocene or at most lowest Pleistocene age [37].

10. The depressions of NW—SE trend (a characteristic feature of the present relief), are the results of deflation by the northwesterly winds of the summer, active in transporting the moving sands. These strings of depressions with more or less parallel axes [23] already existed in the interstadial phases; their forms were inherited by the Recent relief [32]. The mineral composition of the wind-borne sand occurring between the Danube and the Tisza implies that the sand was derived from the drainage area of the Danube, with the garnet and the amphiboles invariably exceeding the volume of the pyroxenes. Of the accessory minerals, tourmaline and kyanite are most characteristic. The sands of Tiszian derivation are distinguished by the abundance of the pyroxene group, particularly of hypersthene. On the basis of his heavy mineral studies, P. SZABÓ has set the separation of the Danubian and Tiszian drainage areas at the Pliocene-Pleistocene boundary; his findings have subsequently been confirmed and completed by B. MOLNÁR [47, 37].

The Holocene commenced in the proximity of the river valleys by a phase of incision and erosion. In the early Holocene the movement of the unconsolidated sands in the parts of the divide not affected by the rivers was fairly intense. The author has proved in a number of instances the denudation of the loess surface and the covering of the denuded area by wind-blown sand. This phase of denudation took place simultaneously with the post-Pleistocene incision of the Danube and Tisza valley, presumably in the fir-birch phase, whereas the displacement of the moving sands is supposed to have occurred in the hazel phase.

In the NW—SE-striking depressions blown by the winds out of the early Holocene wind-laid sands, carbonatic sediments were subsequently precipitated. The author as well as P. KRIVÁN and M. MUCSI have found the uneven surface of the aeolian sand to be overlain first by limestone and then by a calcareous mud separated from the latter by a sharp lithologic limit. The sequence is terminated by an intensely humiferous unit, most frequently consisting of unsorted silt containing more or less fine sand. The carbonate was leached out of the somewhat higher surroundings and transported into the depressions by the ground-water. Its precipitation was due in the first place to the removal of CO_2 by the plants and secondly to evaporation and to the soda content of the water. The chemical composition exhibits no regular variation in space. The molluscan fauna suggests [32, 38] that some of these lakes existed as far back as the Würm, much earlier than the Holocene hazel phase, but even in these there could be no significant precipitation of lime earlier than the oak phase. The deposition of the overlying humiferous layer took place, as revealed by the pollen and mollusc record, in the first beech phase. In the second beech phase (of a more continental turn) the sands locally began to move again and covered here and there the carbonatic formations of the depressions.

3. The Tisza valley

By the term "Tisza valley" is meant the depression eroded by the river at the beginning of the Holocene and filled subsequently with its waste. The area kept on sinking steadily up to the end of the Pleistocene and was filled up in consequence with mostly fluvial deposits. The shape of the area north of the Jugoslavian border recalls a gradually narrowing funnel, some 30 kilometres wide in the south, hardly more than five km at Tiszakécske.

On the basis of the nature of the superficial deposits one can distinguish a Pleistocene loess and a Holocene alluvial surface. The wind-borne sand of the divide, moving in the direction of the valley, is found to cover the loess of the Würm-3 even higher up on the Pleistocene surface. In the deep-lying areas the loess underwent processes of alkali soil formation in fairly large areas, being covered locally by meadow clays and silts, the products of deposition in the backwaters of the floods. The loess layer is 3 to 5 metres thick. Its composition is varied, being more sandy and less compacted in the SW, more massive and richer in silt in the NE. The lower part of the entire loess complex is of a finer grain. It is underlain by a fluvial series and is overlain by clay. This clay horizon is the lowermost clay level of the Tisza valley area. In the environment of Szeged, there is an aquiferous sand layer of fairly great extension in a depth of 10 to 15 metres, dipping into the direction of the valley and rising towards the divide. As a result of the wedging-out of the above-mentioned clay level it enters into immediate contact with the loess layer at a distance of some 10 to 15 kilometres from the river, thus providing a passage for the ground water. At a height of 60 metres above the Adriatic, there occurs a second layer of clay and silt dipping rather conspicuously towards the river. This latter layer is not uninterrupted over the entire area (Fig. 5).

In the course of the Pleistocene the Tisza valley underwent a steady subsidence that continued up to the end of the period, resulting in a thick fluvial fill everywhere in the valley. In the subsiding areas the rivers continually changed their courses and laid down deposits of alluvial-fan type (Fig. 6).

The presumably early Holocene incision of the Tisza scooped out some 20 metres of sediment south of Szeged, some 15 metres at Algyő and 10 to 15 metres farther north. The eroded surface was subsequently covered by a sequence consisting of fluvial sands, coarser at the bottom and growing gradually finer upwards (Figs. 4, 5), overlain by silt, clayey layers and topped by meadow clay. The grading of the coarser deposits at the bottom into the finer ones towards the top [31] reflects the gradual decrease of the waste-carrying capacity of the river and corresponds *to a single cycle of deposition*. The whole sequence is overlain by a thin coating of the youngest alluvium (fine silt, unsorted silt), a member that does not belong any more to the cycle terminated by the meadow clay, being instead a result of conditions changed by

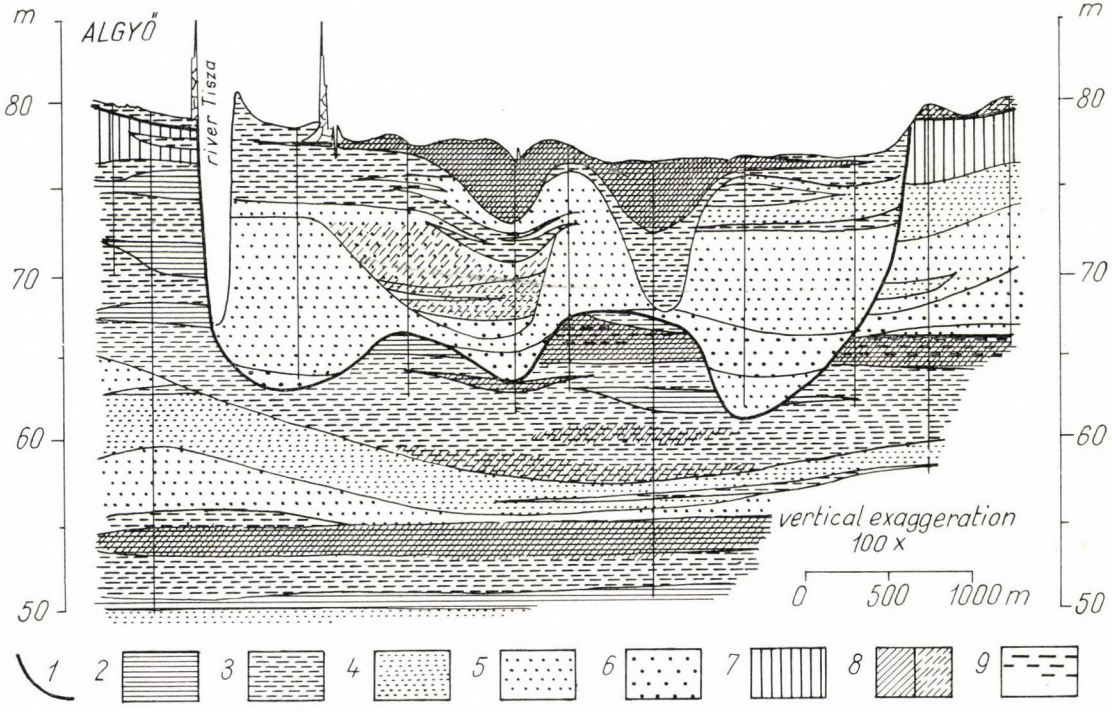
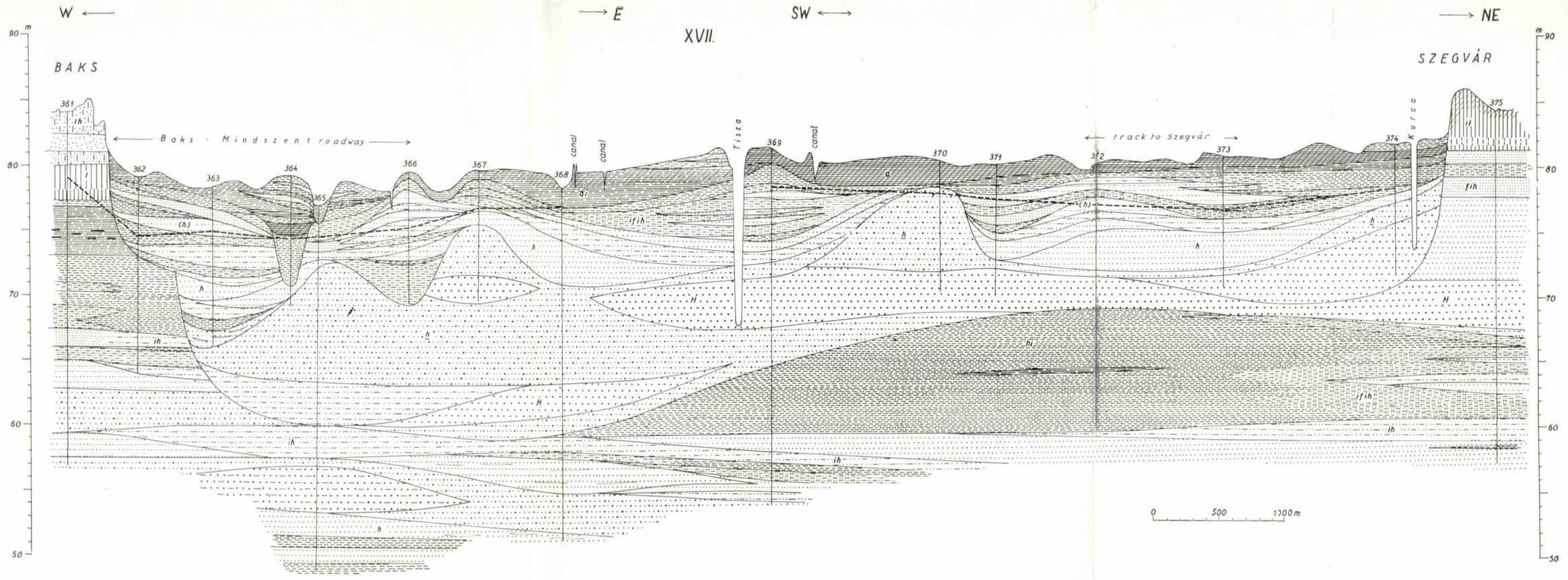


Fig. 5. A cross section of the Tisza valley at Algyő. 1 — Holocene — Pleistocene interface, 2 — clay, clayey fine silt, 3 — unsorted silt, 4 — coarse silt and superfine sand, 5 — fine sand, 6 — medium sand, 7 — loess, 8 — slightly or intensely humiferous layers, 9 — vegetal remains



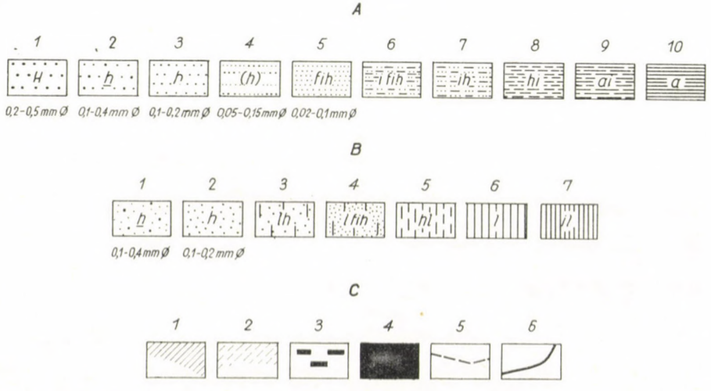


Fig. 6. A cross section of the Tisza valley between Baks and Szegvár. *A*) Fluvial deposits: 1 — medium sand, 2 — medium and fine sand, 3 — fine sand, 4 — fine and superfine sand, 5 — superfine sand, 6 — superfine sand with coarse silt, 7 — fine and superfine sand with silt, 8 — unsorted silt with superfine sand, 9 — clayey fine silt, 10 — clay. *B*) Aeolian deposits: 1 — transition between fine- and medium-grained wind-borne sand, 2 — fine wind-borne sand, 3 — loessy wind-borne sand, 4 — loessy superfine sand, 5 — superfine sandy loess, 6 — loess, 7 — loess with fine silt. *C*) Diverse symbols: 1 — intensely humiferous layers, 2 — slightly humiferous layers, 3 — turfy layers, 4 — turf, 5 — ground water, 6 — Pleistocene-Holocene interface

flood control operations. The clayey terminal member may locally be absent. The youngest floodplain silt is somewhat more sandy near the river. The profiles indicate in a number of instances the erosion of the top parts of the more compacted, clayey deposits.

According to the results of the pollen analysis of the Holocene deposits, there was a hiatus during the fir-birch and hazel phases. The subsequent phase of sedimentation went on uninterrupted from the beach phase to the present.

In 1957 and 1958, two research wells of 500 metres depth were sunk in the Tisza valley. On the evidence of the molluscs furnished by the drill cores, F. BARTHA is inclined to relegate the series of 545 metres depth of the Makó drilling to the Pleistocene. The lithologic and palynologic study of the sedimentary series of the well has, however, induced the author to adopt a different view. Unfortunately, the available material has not warranted a detailed stratigraphic zoning. The well log presents the following general aspect:

0.0 to 0.5 m	loess and loessy sand
0.5 to 29 m	fluvial sand
29 to 32 m	loess; the upper part of the layer is altered
32 to 166.2 m	layers containing exclusively pine pollen (presumably deposited in glacial phases) alternate with varied spectra presumably deposited in interstadial phases (Tilia, Abies, Fagus, Carpinus, Quercus, Picea, Betula)
166.2 to 388 m	the series is very rich in Tertiary forms
388 to 406 m	the pollen spectrum does not lend itself to any meaningful evaluation
406 m	to the bottom: Pinus and Picea are accompanied throughout by thermophilous deciduous trees indicating a warm climate of Tertiary type but present also in the Pleistocene.

As to the heavy mineral assemblages B. MOLNÁR established a change in composition at 173 metres depth, the assemblages looking Tiszian above and Danubian below that limit.

At Szentes a loess-like substance weathered on the top has furnished a glacial pollen assemblage down to 5 metres depth. Between 5 and 81 metres depth the hole has not been cored and the furnished material is unsuited to a palynological evaluation. The heavy mineral assemblages reveal a wind-blown sand of Danubian extraction of some 30 metres thickness intercalated between two series of Tiszian fluvial sands. In the 81 to 92 metres interval there occurs a thick loess layer, humiferous in its top part, with exclusively pine pollen. Between 92 and 100 metres, the sparse pollen content includes some Quercus, Tilia and Ulmus besides Pinus, indicating an interglacial phase. From 100 metres to 102 metres there occurs a wind-borne sand layer, underlain

down to 106 metres by loess, characterized again by Pinus. Between 106 and 113 metres the humiferous silt and clay layers carry very little pollen, with some Tilia besides Pinus near the bottom of the unit. Between 113 and 151 metres there is a fluvial series including several humiferous horizons free of lime, indicating a climate rich in precipitation. The pollen spectrum comprises some Abies, Fagus, Quercus and Tilia pollen. In the varied series from 155 to 221 metres an alternation of glacial and interglacial pollen assemblages is observed. Between 163 and 167 metres there is a third horizon of wind-borne sand. Downward of 211 metres there occur also conceivably washed-in spore forms of Tertiary and even Mesozoic character.

On the basis of the above-described two series, the thickness of the Quaternary sequence is established at a minimum of 160 metres at Makó and of 220 metres at Szentes. The deposits assayed as irrefutably Pleistocene include several horizons of loess and wind-blown sand, buried by fluvial series. Below the change indicated by the pollen assemblages the sands are exclusively of fluvial origin, presumably of Danubian derivation. The compacted deposits below the afore-mentioned limit mainly consist of silt rich in carbonate, markedly different from the finer-grained floodplain deposits. By their marly nature and substantial thickness they appear to be *the deposits of long-lived lakes of considerable extent.*

4. The region east of the Tisza

The limit of this unit towards the Tisza valley in the broader sense is rather vague as the surface gently slopes in the direction of the river.

The surface is covered by loess or by fluvial deposits. Within the latter type of cover, two further types can be distinguished on the basis of the underlying formation which is Pleistocene loess in some instances and the filling of river beds or oxbow lakes in others. The loess is mostly of the waterlogged (infused) type, occasionally even of the marshy variety. In the undrained deep flats it frequently turned into an alkali-type soil. North and northeast of Orosháza there occur also large spots of dry-land loess. The thickness of the loess cover is 2 to 3, seldom 4 metres. The ground water table is generally situated in the underlying deposits. The sedimentary record of the subsiding regions filled up by the rivers indicates a rhythmic alternation of sediments, the latter being a result of the alternation of cycles or erosion and deposition. The filling of the rhythmically subsiding basin and the erosion of the adjacent regions is shown in Fig. 7.

As soon as the valley profile attains a state of equilibrium in the area of erosion, the cycle of erosion currently under way comes to a stop. In the area of deposition the corresponding cycle of deposition is simultaneously terminated by fine-grained sediments. The rivers emerging into the considerably deeper-lying plains down a rather steep valley profile deposit in the initial

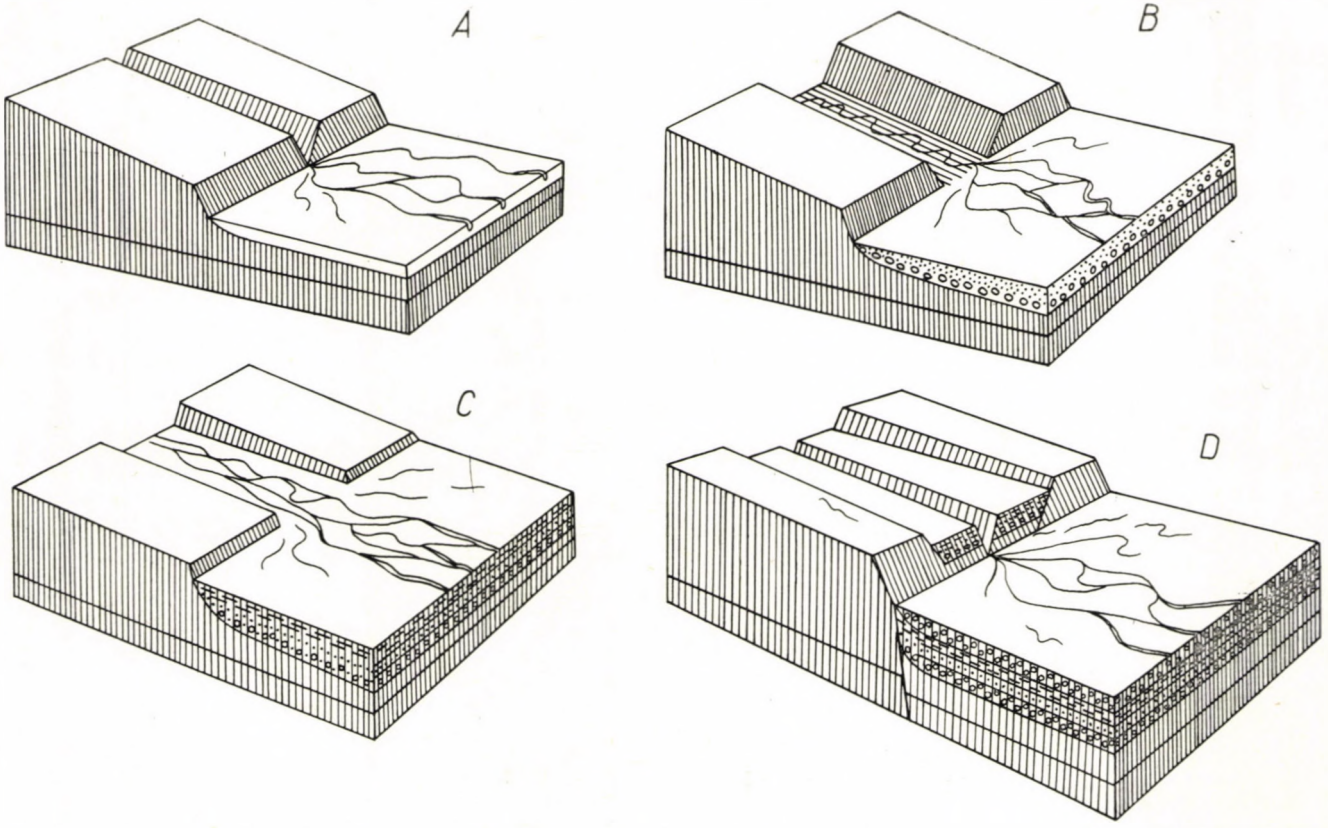


Fig. 7. Deposition by a stream in a phase of *A* — degradation, *B* — equilibrium, *C* — aggradation, *D* — The beginning of a new cycle of deposition as a result of renewed subsidence

stage of the repeated cycles layers of coarse deposits that indicate the beginning of a new cycle of sedimentation.

In the area of erosion the beginning of the new cycle is marked by the incision of the river into the former floodplain, resulting in the appearance of a terrace above the current stream level. A similar conception of the dis-

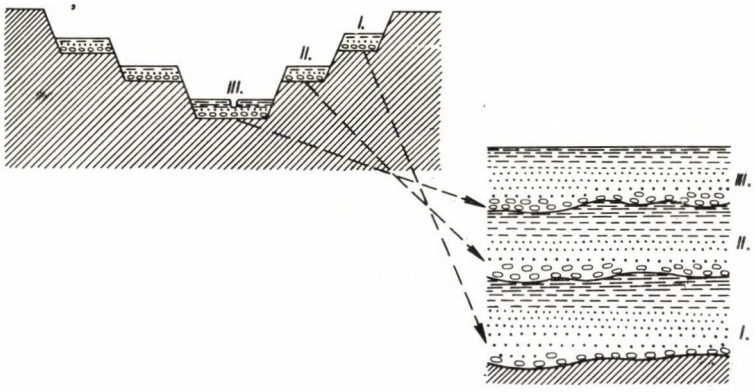


Fig. 8. Cycles of accumulation corresponding to the terraces and cycles of erosion, respectively, of the drainage area

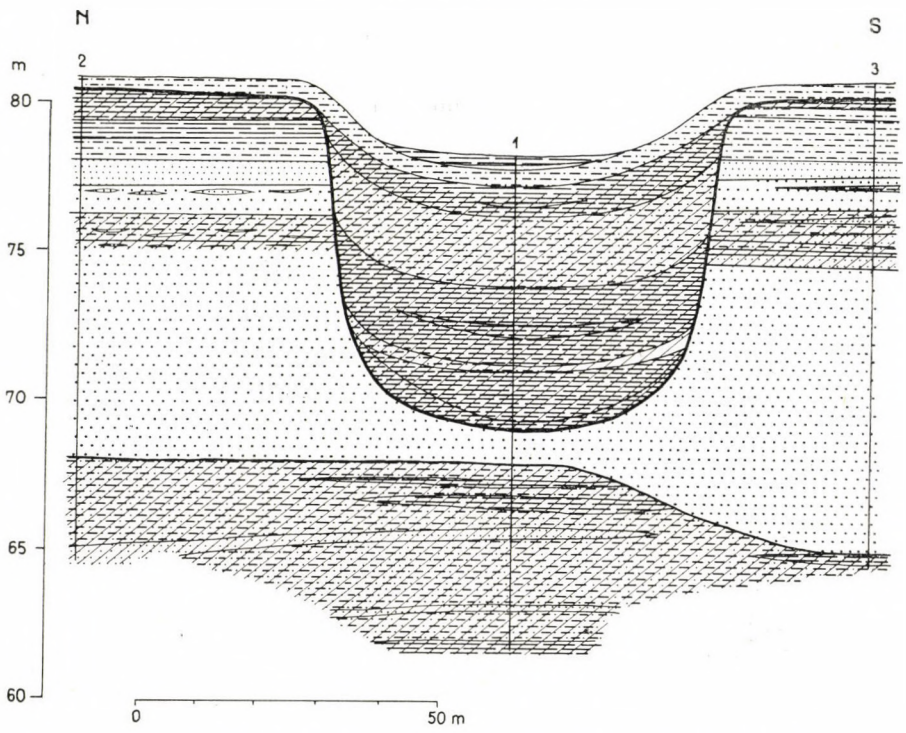


Fig. 9. Oxbow filled up in the Holocene. For the legend see Fig. 5.

tribution of coarser and finer sediments in the terraces is described and illustrated by FOURMARIER [12, vol. 2, p. 1321]. Hungarian authors have also described similar sequences: the sedimentary sequence of a terrace is thus seen to be a diminutive equivalent of a cycle of deposition in the basin.

At the base of the series of the new sedimentary cycle there may occur a more or less marked surface of erosion. This is an obvious result of the increased energy of the river carrying a larger volume of coarser load capable

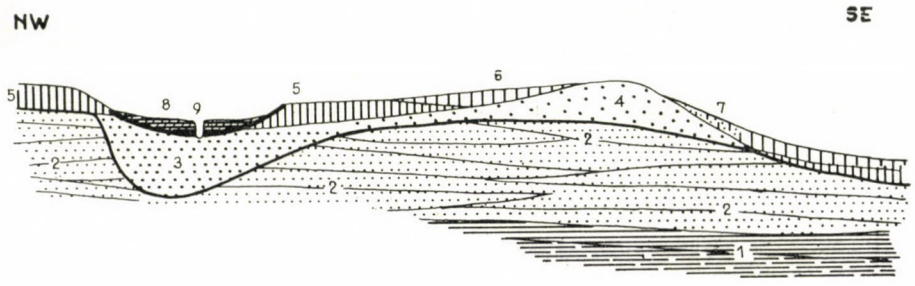


Fig. 10. Generalized profile of the riverbank dune areas east of the Tisza. 1 — clay and silt 2 — fluvial sand of varied composition, 3 — sand filling of a young river bed, 4 — riverbank dune blown out of the fluvial deposits, 5 — loess with fine silt, 6 — loess with superfine sand, 7 — loessy sand, 8 — Holocene clayey deposits, 9 — Recent stream

even in an area of aggradation of a certain erosional activity. Later on in the cycle, increasingly finer deposits are seen to occur in an uninterrupted series of parallel or lenticular layers. (The immediate vicinity of the river valleys is of course an exception.)

The relationships connecting the sedimentary sequences of the terraces with the individual cycles in the basin are illustrated in Fig. 8 [31].

In the area east of the Tisza five cycles of fluvial deposition, not older than the Riss glaciation according to their pollen spectra, could be distinguished down to the depth disclosed by the drillings.

As has been expounded in the case of the Tisza valley, the Holocene deposits represent a single cycle of deposition. The most complete development of the cycle is observed near the river valleys, particularly in the form of the filling of ancient oxbow lakes (Fig. 9).

In the area delimited by the towns of Szentes, Nagyszénás, Kondoros, Mezőberény, Hódmezővásárhely, Orosháza and Békéscsaba, the loess is underlain by a layer of sand exposed on the surface in two oblong spots (Fig. 10).

REFERENCES

1. BACSÁK, GY.: M. Orsz. Meteor. és Földmágnes. Int. Kiadványai. Budapest, 1942. — 2. BACSÁK, GY.: Acta Geologica **3,** 305—346, 1955. — 3. BARTHA, F.: Magyar Állami Földtani Intézet Évi Jelentése 1959-ről, 271—295, 1962. — 4. BULLA, B.: Földtani Közlöny **68,** 33—58, 1938. — 5. BULLA, B.: Acta Geologica **2,** 1—14, 1953. — 6. CAILLEUX, A.: Mém. Soc. Géol. France, N. Sér. **21,** 1—176. — 7. CAILLEUX, A.: Applications à la géographie des méthodes

d'étude des sables et des galets. Rio de Janeiro, 1961. — 8. CHARLESWORTH, K.: The Quaternary Era, Edward Arnold, London, 1957. — 9. CHOLNOKY, J.: M. Tud. Akad. III. Oszt. Közl. **42,** 101—121, 1925. — 10. DÁVID, P.: A study of roundness of wind-blown sand from Hungary and the Canadian Great Plains. Dept. of Geol., McGill Univ., Montreal, 1961. (Thesis.) — 11. FINK, J.: Mitteil. d. Geol. Gesellschaft in Wien **54,** 1—25, 1962. — 12. FOURMARIER, P.: Principes de géologie. Masson et Cie., Paris, 1950. — 13. HALAVÁTS, GY.: Magyar Királyi Földtani Intézet Évkönyve **9,** 101—173, 1895. — 14. HORVÁTH, A.—ANTALFI, S.: Annales Biol. Hung. **2,** 417—428, 1954. — 15. HORVÁTH, A.: Állattani Közl. **44,** 1—2—7, 1954. — 16. HORVÁTH, A.: Állattani Közlemények **44,** 171—188, 1954. — 17. HORVÁTH, A.: Acta Biologica. **8,** 173—192, **9,** 101—115, **10,** 131—146, 1963, 1964, 1965. — 18. JASKÓ, S.: Földtani Közlöny **77,** 26—28, 1953. — 19. KRETZOI, M.: Acta Geol. **2,** 67—79, 1953. — 20. KRIVÁN, P.: Acta Geol. **2,** 79—91, 1953. — 21. KRIVÁN, P.: Acta Geol. **2,** 91—108, 1953. — 22. KRIVÁN, P.: Magyar Állami Földtani Intézet Évkönyve **43,** 363—503, 1955. — 23. LÁNG, S.: Közl. Szegedi Tud. Egy. Földrajzi Int., 1960. — 24. MIHÁLTZ, I.—FARAGÓ, M.: Alf. Tud. Évkönyv 1—14, 1944—45. — 25. MIHÁLTZ, I.: A Duna—Tisza csatorna geológiai viszonyainak tanulmányozása. (Les conditions géologiques du canal Danube—Tisza.) Földművelésügyi Minisztérium Kiadv. Budapest, 3—12, 1947. — 26. MIHÁLTZ, I.: Földtani Közlöny **82,** 51—57., 1952. — 27. MIHÁLTZ, I.: Magyar Állami Földtani Intézet Évi Jel. 1950-ről, 113—141, 1953. — 28. MIHÁLTZ, I.: Acta Geologica **2,** 109—120, 1953. — 29. MIHÁLTZ, I.: Magyar Állami Földtani Intézet Évi Jelentése 1951-ről, 61—69, 1954. — 30. MIHÁLTZ, I.—UNGÁR, T.: Földtani Közlöny **84,** 17—28, 1954. — 31. MIHÁLTZ, I.: Acta Min.-Petr. **8,** 51—62, 1955. — 32. MIHÁLTZ, I.—MUCSI, M.: Hidrológiai Közlöny **10,** 463—471, 1964. — 33. MIHÁLTZ, I.: Hidrológiai Közlöny 1965. (In press). — 34. MIHÁLTZ, I.: Acta Biol., **11,** 1965. (In press). — 35. MOLDVAY, L.: Acta Miner.-Petr. 74—109, 1961. — 36. MOLNÁR, B.: Földtani Közlöny **91,** 300—315, 1961. — 37. MOLNÁR, B.: Acta Min. Petr. **15,** 43—51, 1962. — 38. MUCSI, M.: Földtani Közlöny **93,** 373—386, 1963. — 39. MUCSI, M.: Földtani Közlöny 1965 (In press). — 40. PÁVAI—VAJNA, F.: Magyar Állami Földtani Intézet Évi Jel. 1951-ről, 69—73, 1953. — 41. PÉCSI, M.: A magyarországi Duna-völgy kialakulása és felszínalaktana (Evolution and relief of the Hungarian section of the Danube Valley. Akadémiai Kiadó, Budapest, 1959. — 42. SCHERF, E.: Magyar Állami Földtani Intézet Évi Jelentése 1925—28-ról, 274—302, 1935. — 43. SCHERF, E.: Versuch einer Einteilung des ungarischen Pleistozäns auf moderner polyglazialistischer Grundlage. Verhandlungen der III. Intern. Quartär-Konferenz. Wien 1938. — 44. SOERGEL, W.: Die Vereisungskurve. Borntraeger, Berlin, 1937. — 45. SÜMEGHY, J.: A Tiszántúl. (The region beyond the Tisza.) Magyar Állami Földtani Intézet Kiadványai, Budapest, 1944. — 46. SÜMEGHY, J.: Magyar Állami Földtani Intézet Évi Jel. 1950-ről, 233—263, 1953. — 47. SZABÓ, P.: Földtani Közlöny **85,** 442—456, 1955. — 48. SZABÓ, P.: A Szeged városi fürdői mélyfúrás homokrétegeinek vizsgálata. (Study of the sands traversed by the boring at the Municipal Baths of Szeged.) Lecture delivered before the Association of Hungarian Geologists 1956. — 49. SZAFER, W.: Ann. de la Soc. Géol. de Pologne **92,** 1—99, 1953. — 50. SZÓNOKI, M.: Földtani Közlöny **93,** 235—243, 1963. — 51. VAN DER VLERK—FLORSCHÜTZ: Verhand. Kon. Ned. Acad. V. Wet. Afd. Naturkunde, Deel, **20/2,** 1—57, 1953. — 52. ZÓLYOMI, B.: Acta Biol. **4,** 367—430, 1953.

ОБРАЗОВАНИЯ НА ПОВЕРХНОСТИ ЮЖНОЙ ЧАСТИ БОЛЬШОЙ ВЕНГЕРСКОЙ НИЗМЕННОСТИ

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Резюме

Эоловые осадки Большой Венгерской Низменности обусловлены климатическими изменениями и развиты достаточно полно для того, чтобы подразделить их на стратиграфические горизонты. Предпосылки для их сохранения существовали в районах (междуречье Дуная и Тиссы), отличавшихся сравнительно более медленным опусканием и за определенный промежуток времени (конец плейстоцена).

В районах более интенсивного опускания, заполняющихся речными осадками, осадконакопление происходит циклично в зависимости от движений земной коры, повторяющихся время от времени. В пределах отдельных циклов обнаруживается тенденция к утончению гранулометрического состава, так что рассматриваемые осадки поддаются разделению. Фациальные изменения речных осадков независимы от смены климатических условий плейстоцена.

THE MANIFESTATIONS OF QUATERNARY TECTOGENESIS IN THE MOUNTAINS OF HUNGARY

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The marginal zones of the low mountains of Hungary are characterized as a rule by long Quaternary anticlines up to 6 kilometres wide and 50 to 100 metres high. Their origin can be explained by the assumption of the upthrust of chains of Permian-Mesozoic blocks along the margins of the mountains, simultaneously with the uplift of the central masses. As a result of the upthrust, longitudinal thrust faults and transversal grabens came into existence in the uplifted Pleistocene cover. In certain sections, the amplitude of the upthrust of the Mesozoic block chains attains as much as 300 metres. The anticlines are accompanied by fore- and rear-deeps.

In the present brief review only the essential phenomena, namely the clues to the understanding of the process of Quaternary tectogenesis shall be enumerated. This topic does not constitute a field whose study could be separated from that of the older phases of tectogenesis. However, the knowledge of the Quaternary processes may lead to the more profound understanding of tectogenesis as a whole.

The study of Quaternary tectonics is based among others on physiographic data. The study of the relief frequently offers results that may be substituted for the direct observation of the dislocations of the strata if such an approach is found to be impracticable. From the point of view of methodology the essential feature of the results presented here is precisely the establishing of the physiographic counterparts of the long known typical tectonic features.

The Quaternary series of the Hungarian mountains is exclusively terrestrial. Its thickness is considerably larger on the periphery of the mountains than in the elevated regions proper. From the point of view of tectonics it is part of the "superstructure" whose movements are directly or indirectly governed by those of the Mesozoic "infrastructure". The first to study the structural features of the Quaternary was PÁVAI-VAJNA who between 1917 and 1930 constructed a series of unpublished maps for the Neogene of Southeast Transdanubia. He also proved the existence of anticlines and synclines in the Pliocene and Pleistocene sedimentary series.

In the Mecsek Mountains VADÁSZ and WEIN have proved a number of phases of structural evolution. Amongst these, the post-lower Cretaceous Austrian, the Pliocene (intra-Pannonian) Rhodanian and the late Pliocene

Valachian are the most important. In the Valachian phase the Mesozoic of the northern and southern foreland of the mountain chain of N—W strike was upthrust and also overthrust on the young deposits of the forelands.

Similar upthrusts in the Pleistocene can be proved on stratigraphic as well as on morphologic (physiographic) evidence. A number of borings have been sunk in a profile which traverses the foreland of the mountains. In this section PÁVAI-VAJNA succeeded in establishing the presence of a young anticline by measuring the dips in the Pliocene strata. The well logs have revealed that the early Pleistocene loessy deluvium which was originally deposited on a more or less even piedmont surface (the loess having an approximately constant thickness) today constitutes an anticline of 70 to 100 metres amplitude presumably created by the upthrust of the Mesozoic fault blocks underlying the foreland of the mountains (Fig. 2). The advance of the series towards the northern foreland could also be observed, which is accompanied by the development of an extended foredeep. A characteristic acessory of the anticline is a "read-deep" that could be traced along the entire length of the young upthrust. The "rear-deep" may be a well-defined depression locally, but elsewhere it is just a low hummocky area or col.

As a result of the arching, the Pliocene and Pleistocene series was dissected along longitudinal shear fractures into blocks of various sizes. Along the top of the anticline there is a deep erosional valley presumably anticipated by a wedge-shaped collapse structure. The dip of the flanks of the anticline does not exceed a few degrees. Along the shear fractures one may presume displacements and flexions of as much as 20 to 30 metres amplitude but the strata did not reveal any positive tectonic fractures as yet. The valleys of the rivulets traversing the anticline are of the antecedent variety, a fact that is a further important physiographic proof of the uplift.

In the eastern continuation of the anticline, the movement of the infrastructure underlying the Tertiary and Quaternary cover can also be ascertained (Figs. 3, 4). At Szászvár the upthrust Mesozoic fault blocks were uplifted by 260 metres as compared to their position in the Pleistocene. The basis of the comparison is a piedmont surface which was deplaced by the said amount. If the position of the fault block chain is referred to the foredeep four kilometres away, the amplitude of the uplift can be established at 300 metres. The upthrust took place while the whole bulk of the mountain was being uplifted.

In Fig. 4 the northern margin of the Mecsek Mountains is represented in a somewhat unusual way. According to the techniques of terrace research, the elevations are counted from the valley bottoms rather than from the sea level. This construction, called the method of relief reduction, often reveals remarkable features of the relief which cannot be expressed at all by means of the contours counted from the sea level.

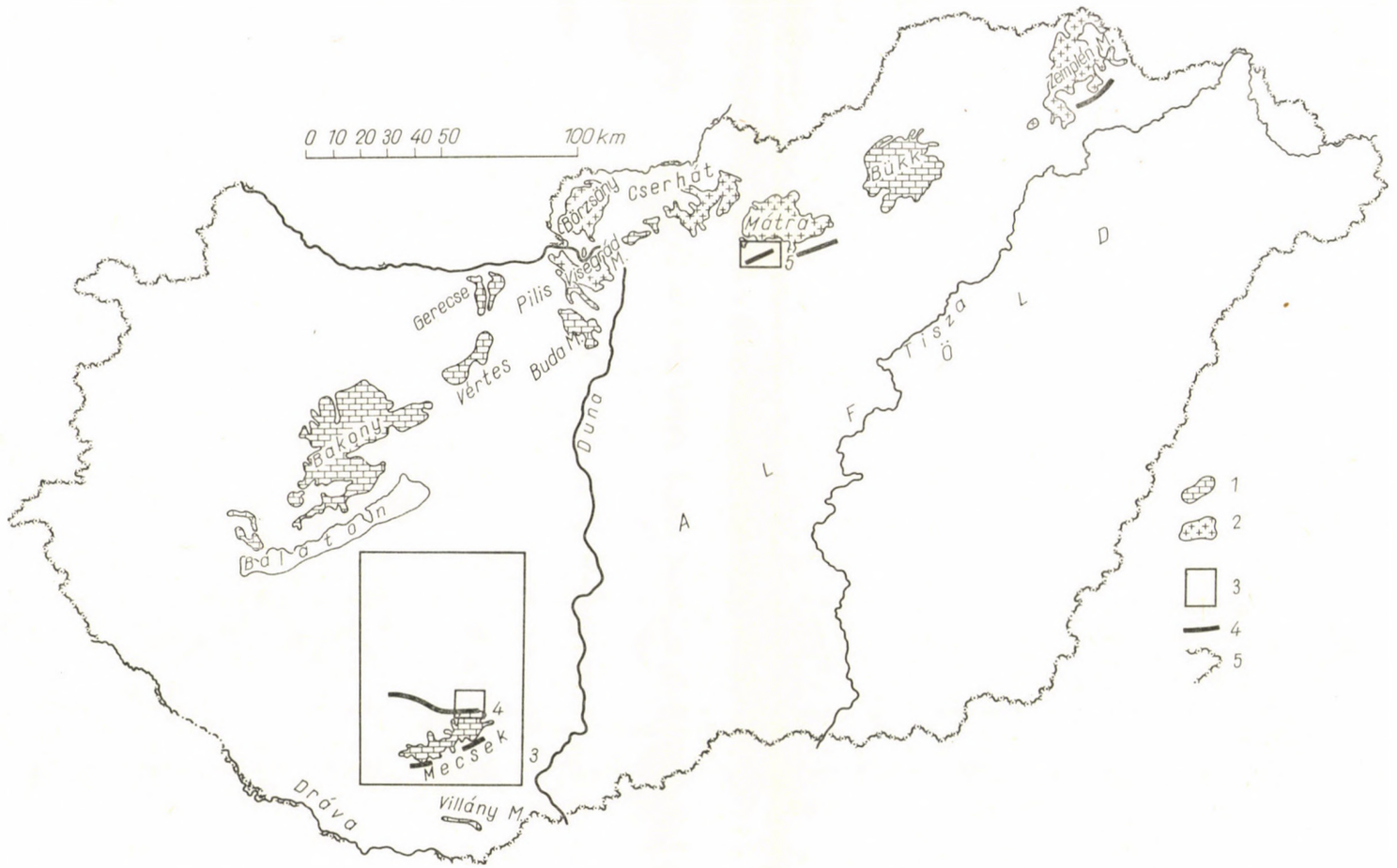

Fig. 1. Sketch map of the Hungarian mountains. Constructed by L. MOLDVAY. Legend: 1. — Mountain consisting of largely Mesozoic rocks (elevation above 300 metres), 2. — Mountain consisting of Tertiary volcanics, 3. — Outlines and serial numbers of the detail maps, 4. — Quaternary arching with upthrusts and longitudinal faults, 5. — Country border

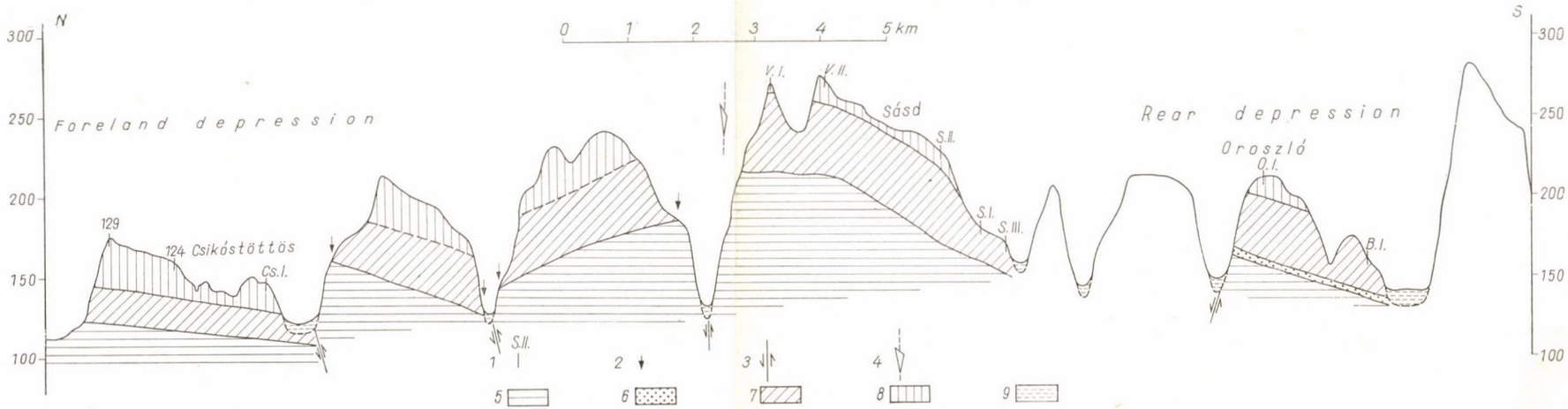

Fig. 2. Profile through the northern foreland of the Mecsek Mountains, Quaternary anticline. Constructed by L. MOLDVAY. Legend: 1. — Borehole, 2. — Outcrop, 3. — Fault or flexure, 4. — Deeply incised sections of transverse streams, 5. — Pliocene (upper Pannonian) clay and sand, 6. — Lower Pleistocene alluvial gravel and sand, 7. — Lower and middle Pleistocene deluvial loess, 8. — Upper Pleistocene loess, loessy sand and wind-borne sand, 9. — Holocene valley filling.

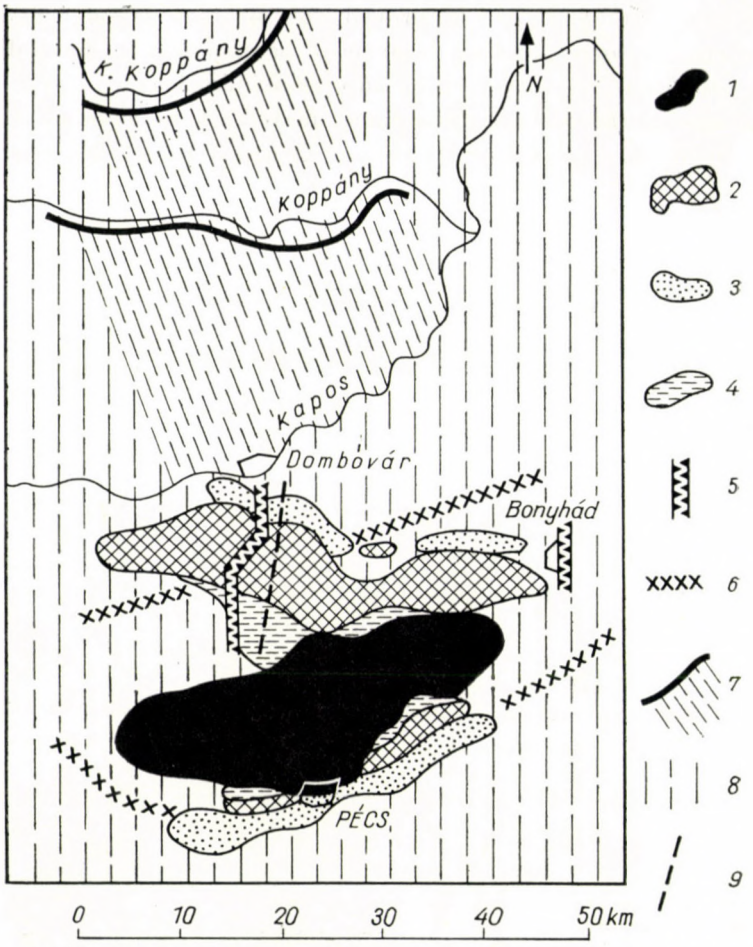

Fig. 3. Morphotectonic map of the Mecsek Mountains. Constructed by L. MOLDVAY. Legend: 1. — Pre-Pleistocene surface of the mountains, 2. — Quaternary arching with upthrusts, and longitudinal faults, 3. — Foredeep, 4. — "Rear-deep", 5. — Transverse graben, 6. — Limit of the crystalline basement according to Gy. WEIN, 7. — Longitudinal fault block of SE-dipping flat surface, 8. — Hummocky area, unspecified, partly problematic, 9. — Profile line (see Fig. 2).

The Pleistocene anticline of the Mecsek Mountains is locally traversed by young grabens. In these the Pliocene series is situated 50 to 100 metres lower than without. As a result of erosion, however, the deposits laid down after the subsidence of the grabens are not more than 20 metres thick.

Evidence of the Quaternary upthrust of the Permian-Mesozoic fault-block chains is not lacking in the southern foreland of the Mecsek Mountains, either. However, in this region the upthrust did not result in the formation

of a continous arching. It can be proved only on two stretches of piedmont surface where the corresponding "rear-deep" is also seen to have developed. The upthrust blocks are traversed by antecedent incisions.

Findings in the Mecsek Mountains incited us to examine the young marginal displacements in the Mátra and Zemplén Mountains, too. Till this

Fig. 4. Morphotectonic map of the Northern foreland of the Mecsek Mountains. Detail. Constructed by L. MOLDVAY. Legend: 1. — Uplifted Mesozoic segment of late Pliocene—early Pleistocene piedmont surface, 2. — Pre-piedmont surface, 3. — Level of denudation, unspecified, 4. — Uplifted section of valley profile, 5. — Upthrust in the Valachian phase according to Gy. WEIN, 6. — Difference of elevation between the valley-bottom relief and the mountain-top relief, in metres

day these mountains were regarded to be devoid since the Pliocene of any regular tectonic pattern of movements. In the southern foreland of the Mátra Mountains the dip of the Pliocene strata was supposed to be due to uneven compaction and insignificant faulting. It has turned out, however, that the southern margin of both the Mátra and the Zemplén Mountains is arched to a certain degree. In the area shown in Fig. 5 the contour map exhibits a slope of no particular interest. However, the relief-reduction map referring the levels

Fig. 5. Morphotectonic map of the southern foreland of the Mátra Mountains. Detail. Constructed by L. MOLDVAY. Legend: 1. — Mountain-top level, 2. — "Rear-deep" and its axis, 3. — Axis of rising anticline, 4. — Difference of elevation between the valley-bottom relief and the mountain-top relief, in metres

to the valley bottoms brings out sharply a depression of NE—SW strike, several kilometres wide and associated with an arch of similar size. Further east the uplift is so strong as to be apparent even on the contour map. Similarly marked forms are also found on the southern margin of the Zemplén Mountains.

The arching is of tectonic origin: according to dip measurements by Gy. Vigh there is a flat anticline of Pliocene deposits with NNE—SSW strike that stretches between Ecséd, Nagyréde and Gyöngyöstarján. For a breadth of 3 km the anticline has a maximum elevation of 40 metres. In the Mecsek Mountains the uplift amounted to 50, locally to 70 metres within an interval of 3 kilometres. The top of the anticline of Nagyréde also features an axially incised valley.

The similarity between the forelands of the Mecsek Mountains on the one hand and the Mátra and Zemplén Mountains on the other is rather striking. On the southern margin of the adjacent Bükk Mountains K. Balogh has established the upthrust of Triassic fault blocks accompanied by a similar evolution of the relief. These movements have also displaced the Miocene. The foreland of the Bükk Mountains has not been examined for traces of Quaternary movements, but the anticline in front of the Mátra Mountains suggests a similar marginal upthrust of the fault blocks of the Mesozoic basement, smoothed out and attenuated by the unconsolidated young sedimentary cover.

In the southern piedmont area of the Zemplén Mountains, the corresponding anticline could be proven between Erdőbénye, Tolcsva and Sárospatak, striking in a NE—SW direction. In its hinterland near Erdőbénye there are chains of fault blocks separated by longitudinal faults. The dip of the strata of the fault blocks is opposed to the slope of the relief. The layers of Miocene limnoquartzite has 5 to 10° of dip. These blocks remind of the Pannonian plateaux but owing to their rigidity they are more shattered and reveal much more structural detail.

Although the detailed examination of the interior of the mountains for traces of movements of this type is still a task for the future, it seems to be justified to state that the marginal upthrusts are the most conspicuous features of the young structural evolution besides the well-known and considerable uplift of the mountains. These movements, apparently intermittent, exhibit the same overall tendency throughout their history of evolution. Broadly speaking it is erroneous to assume the mountains to be surrounded by simply subsiding fault block chains.

The workers in this country generally attributed the upthrusts to horizontal compression acting in a NW—SE direction, but upthrusts resulting from an upward-directed vertical pressure seem to offer a more plausible explanation of the case (Szádeczky, Beloussov, Gzowsky).

According to high-precision levelling data as presented by BENDEFY (from the years 1922 through 1934 and 1951 through 1958), the central massifs of the Mecsek and Mátra Mountains are at present sinking with respect to the surrounding regions. In the Bükk and Zemplén Mountains it is the central massifs that rise faster. These data tend to prove the independent, separate movement of the individual fault-block units of the mountains.

The intense and manifold structural displacement of the surface, as established above, as well as the as yet unexplained aspects of the process, warn us against unjustified hypotheses concerning peneplanes and piedmont surfaces. It is particularly the assumption of a large number of close-spaced levels of denudation that seems to be little warranted.

REFERENCES

BENDEFY, L.: Acta Geologica **8,** 395—411, 1964. — BELOUSSOV, V. V.: Osnovniye voprosy geotektoniki. Gos. Geol. Izdat. Moscow, 1962. — BALOGH, K.: Földtani Intézet Évkönyve **48,** 2, 1964. — GZOWSKY, M. V.: Tectonophysical correlation of the latest tectonical movements with seismicity, gravity anomalies, magmatism and deep-seated processes within the URSS. Izdatel'stwo Nauka, Moscow, 1964. — KÖRÖSSY, L: Földtani Közlöny **93,** 153—172, 1963. — MOLDVAY, L.: Földtani Intézet Évi Jelentése az 1957—58-ról, 201—216, 1961. — MOLDVAY, L.: Földtani Intézet Évi Jelentése 1962-ről, 105—110, 1964. — PÁVAI-VAJNA, F.: Földtani Közlöny **55,** 63—85, 1925. — PÉCSI M.: Földrajzi Közlemények **11,** 195—212, 1963. — PÉCSI, M.: Földrajzi Értesítő **13,** 1—29, 1964. — SCHMIDT ELIGIUS, R.: Geomechanika. Akadémiai Kiadó, Budapest, 1957. — SCHMIDT ELIGIUS, R.: Földtani Intézet Évi Jelentése 1959-ről, 425—437, 1962. — SZÁDECZKY-KARDOSS, E.: Acta Geol. **8,** 433—454, 1964. — SZEBÉNYI, L.: Földtani Közlöny **85,** 425—441, 1955. — VADÁSZ, E.: A Mecsek-hegység. (The Mecsek Mountains.) Magyar Tájak Földtani Leírása. I. M. Áll. Földt. Int. Budapest, 1935. — VADÁSZ, E.: Magyarország földtana. (The geology of Hungary.) Akadémiai Kiadó, Budapest, 1960. — VIGH, GY.: Földtani Intézet Évi Jelentése az 1933—1935-ről, 653—731, 1939. — WEIN, GY.: Földtani Intézet Évkönyve **49,** 759—768, 1961. — WEIN, GY.: Acta Geologica **8,** 347—355, 1964. — WEIN, GY.: Bányászati Lapok. 1964. (In press.)

ПРОЯВЛЕНИЯ ЧЕТВЕРТИЧНОГО ТЕКТОГЕНЕЗА В СРЕДНЕГОРНЫХ ОБЛАСТЯХ ВЕНГРИИ

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Резюме

В краевых полосах венгерских средних гор образовались четвертичные антиклинальные формы шириной 5—6 км и высотой 50—100 м. Формирование их можно объяснять взбросом вдоль краев массивов пермомезозойских глыбовых гряд, что произошло одновременно с поднятием ядра массивов. Вследствие взброса в приподнятой плейстоценовой кровельной толще формировались продольные разломы и поперечные грабены. На некоторых участках высота взброса мезозойских глыбовых гряд достигает даже 200—300 м. Антиклинали сопровождаются тыловыми впадинами.

LITHOLOGIC AND GEOLOGIC STUDY OF THE QUATERNARY DEPOSITS OF THE GREAT HUNGARIAN PLAIN (ALFÖLD)

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The Quaternary evolution of the Great Hungarian Plains suggests a subdivision of the region into two large units, the land between the Danube and Tisza rivers on the one hand and the land east of the Tisza, on the other.

It has been possible to determine the thickness and extension of the aeolian deposits between the Danube and the Tisza by grain shape studies (Figs. 1—2). The heavy mineral assemblages of riverlaid Recent deposits offer a clue for the distinguishing of the fossil deposits of the two large rivers, the Danube and the Tisza, and their tributaries (Fig. 3). On this basis the thickness of the Quaternary deposits of the Tisza and its tributaries could be established for most of the area east of the Tisza (Figs. 4, 5, 6).

Between the layers of aeolian deposits derived from the floodplain of the Danube and laid down in the land between Danube and Tisza, there occur several intercalations of Tiszian deposits, wedging out towards the west. The isopach map of the aeolian layers and of the deposits of the Tisza and its tributaries, reflects the influence of the basement on the one hand and that of the Quaternary crustal movements on the other.

In the upper Pliocene, after the withdrawal of the lower Pliocene brackish sea from the Carpathian Basin, the Alföld became an area of fluviolacustrine deposition. Here and there, the fluvial deposits of the Pleistocene and Holocene are observed to directly overlie the marine Pannonian. Young crustal movements displaced the Pannonian to various depths. As a result, the subsequent history of the individual parts of the basin proceeded along different lines (KERTAI 1957, KŐRÖSSY 1957, 1963, 1964, PÉCSI 1959, BULLA 1962).

As to the history of the land between Danube and Tisza, several authors have developed a number of hypotheses that fall under two main heads. According to the one, the region is an alluvial fan of Pleistocene age deposited by the Danube. The depressions on the surface, with a southeasterly trend, represent according to this notion a number of ancient Danube beds left behind by that river in the course of its westward shift in the Pleistocene and scooped out by the wind in Recent times (TREITZ 1905, BULLA 1951, 1953, 1963, SCHERF 1936, SÜMEGHY 1950, URBANCSEK 1962, 1963).

The other main hypothesis is based upon the fact that the land between Danube and Tisza is covered by a thick aeolian series. The Danube is supposed to have roamed about in this region only up to the Pleistocene or in the lowermost Pleistocene at the latest, having traversed the same in a roughly southwesterly general direction. The depressions are supposed to be due en-

tirely to the dominant wind rather than to the incision of the Danube (MIHÁLTZ 1947, 1950, 1952, KRIVÁN 1953, DÁVID 1955, HORVÁTH 1952, 1963, MOLNÁR 1962).

Lately, a gradual approach between the two schools of thought has been evident. The detailed investigation of the deposits has convinced the majority of the workers that the alluvial fan of the Danube did not extend to the whole region between Danube and Tisza in the entire Pleistocene, which was restricted, as a matter of fact, to the northern part of the area (PÉCSI 1959, RÓNAI 1956, 1961, ERDÉLYI 1955, 1960, FRANYÓ 1961). In the area not scanned by the river an aeolian series of considerable thickness formed during part of the Pleistocene.

Having studied the Szentes—Baja profile of 30-meter drillings, with a SW—NE strike, and the samples obtained from the research borehole at Felsőszentiván (the latter being nearly 80 metres deep), I. MIHÁLTZ (1950, 1958) recognized that down to the depth reached by the drillings, the sedimentary sequence consists entirely of windblown sand and loess. His statements were based on the grain-shape and the grain-size analyses made by him, pollen analyses made by M. FARAGÓ and finally on A. HORVÁTH's analysis of the Gastropod fauna (1952, 1963). By the grain shape analysis of the samples obtained from some 70 artesian wells, the present author has completed MIHÁLTZ's findings for the entire area of the broad elevation between Danube and Tisza. The author's results are based on the statistic grain shape analysis method first proposed by MIHÁLTZ and UNGÁR (1954) and further developed by DÁVID (1955) and himself (MOLNÁR 1961). By the study of the Recent wind- and river-laid sandy deposits these authors have recognized four basic grain shape types. The method resembles the other well-known visual grain shape analysis procedures (CAILLEUX 1952, PETTIJOHN 1957, SCHNEIDERHÖHN 1954).

The grains of Class 1. are angular, showing no trace of wear, having smooth edges and fracture surfaces with a great diversity of shapes. In Class 2. the apices are worn off and the edges slightly frosted. In Class 3. the edges are worn off and the surfaces exhibit readily visible frosting. In Class 4. the edges are completely worn off, the surface is smooth but frosted and the grains are oval or spherical. In the case of the aeolian deposits between Danube and Tisza, Class 4. is to be identified with the spherical frosted (rond mat) class as defined by CAILLEUX (1952).*

It has been established that in the Alföld the predominance of Classes 1. and 2. implies the deposits to be fluvial whereas aeolian deposits are characterized by the predominance of Classes 3. and 4. The analysis is performed as a rule on the 0.125 to 0.25 mm fraction, on 200 grains in every instance (MOLNÁR 1961, 1962).

The results of the study of the above-mentioned artesian wells have been plotted in graphs and grouped in profiles. One of these is shown in Fig. 1. It traverses the broad elevation between Danube and Tisza in an E—W

* These classes can of course be distinguished just as well by the likewise visual *cpv* method whose power of resolution is, however, considerably greater.

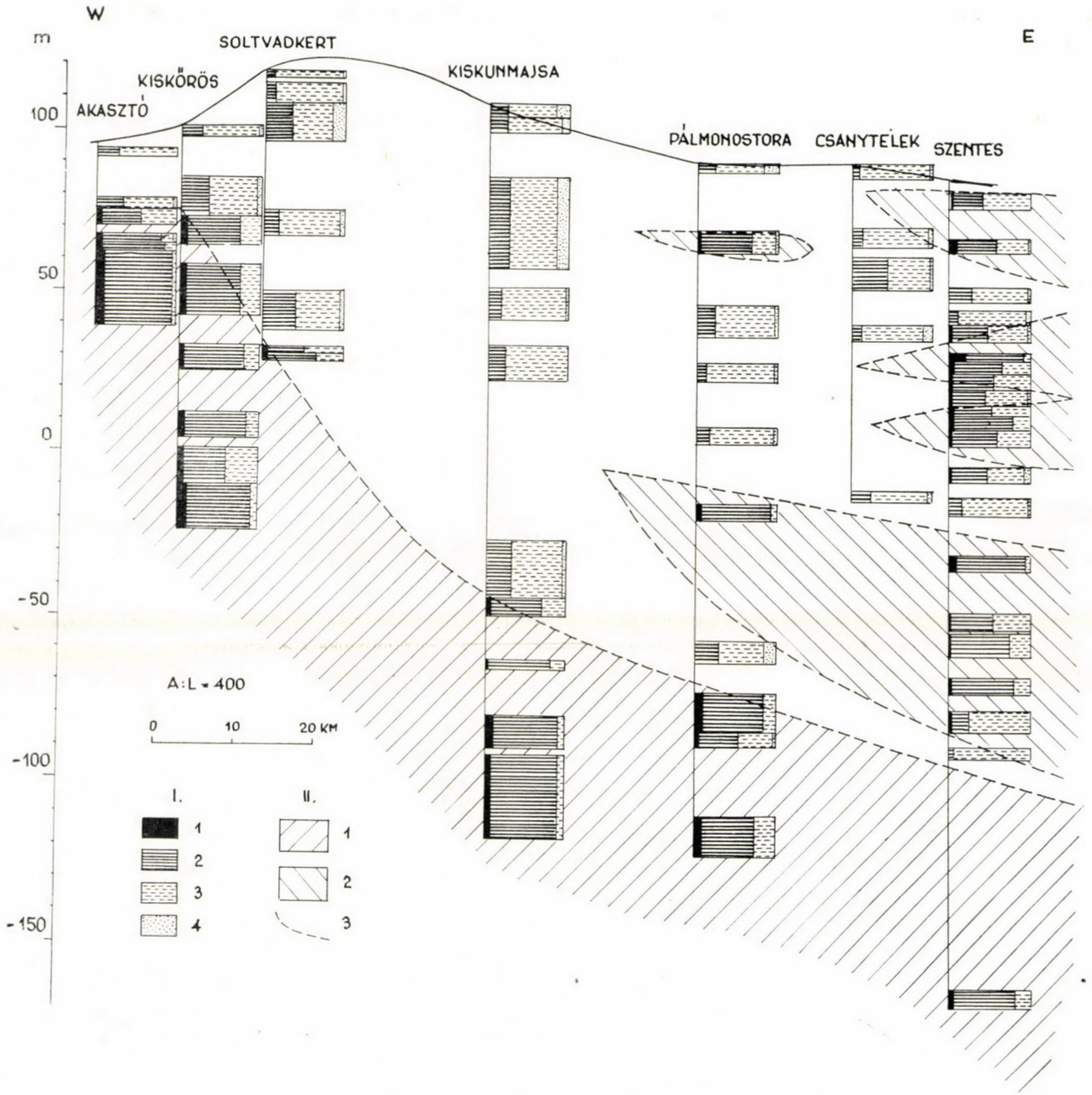

Fig. 1. E—W profile of the aeolian and river-laid deposits through the middle of the land between Danube and Tisza.
I. Grain shape. 1. — Sharp angular, 2. — Subangular, 3. — Rounded, 4. — Intensely rounded grains.
II. Sedimentary type. The empty surfaces represent aeolian deposits. 1. — Fluvial deposits of Danubian origin. 2. — Fluvial deposits of Tiszian origin. 3. — Limit of the fluvial against the aeolian deposits

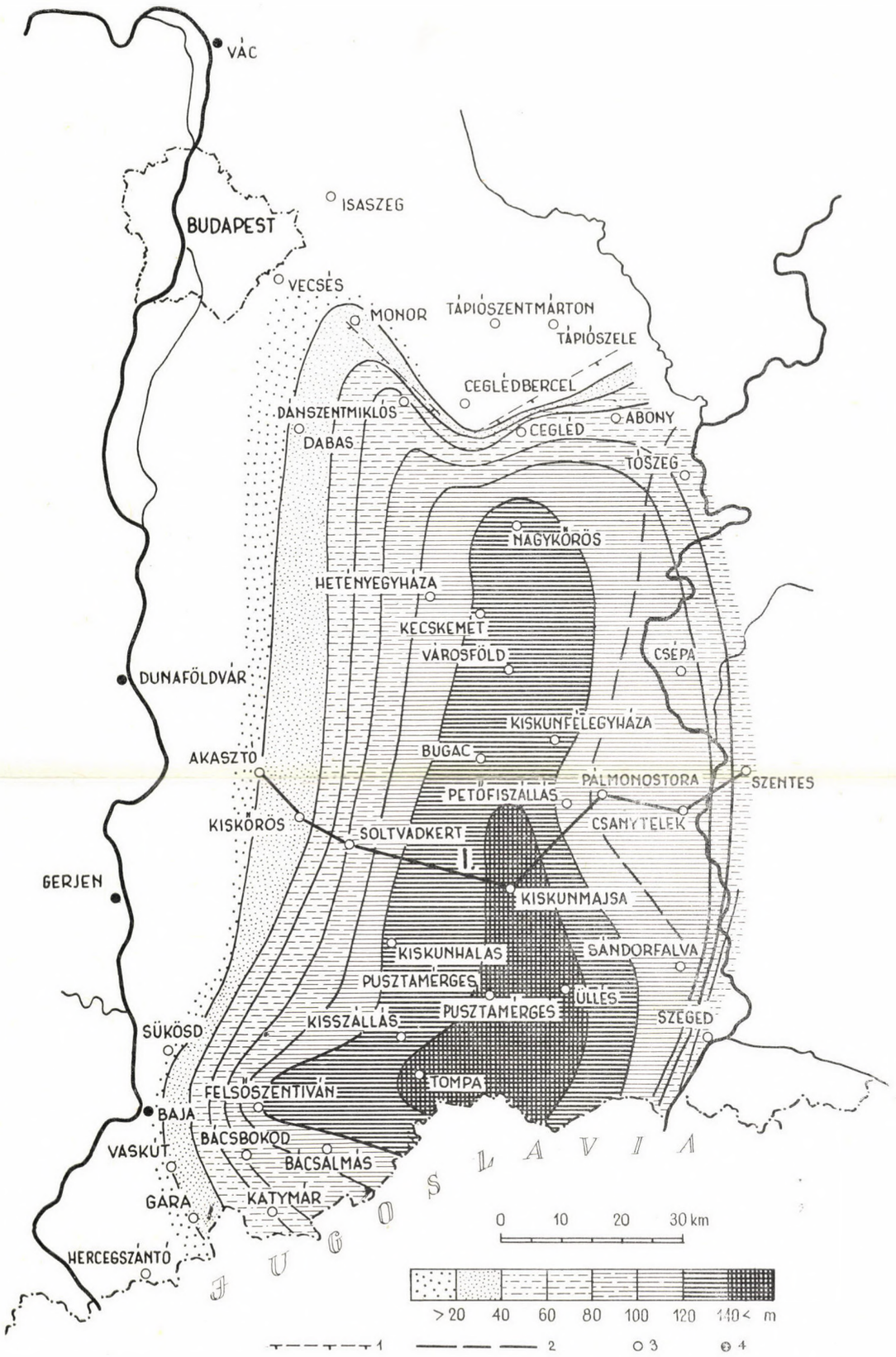

Fig. 2. Isopach map of the aeolian deposits between Danube and Tisza. 1. — Fault-line. 2. — Western limit of the fluvial interbeddings of Tiszian deposition. 3. — Sites of the examined boreholes. 4. — Sampling localities of examined Recent fluvial sands

Fig. 3. Predominant heavy minerals of the Tiszian and Danubian fluvial deposits

direction. The limit between the aeolian and river-laid deposits is readily discernible. The aeolian deposits derived from the floodplains of the Danube are seen to grow thicker and to sink deeper towards the east. In the east, the fluvial intercalations between the aeolian layers become increasingly frequent. As revealed by their heavy mineral assemblage, however, these intercalations were deposited by the drainage system of the Tisza.

The profiles indicating the extension on the surface and underground of the aeolian deposits can be profitably employed in constructing the isopach map of these same deposits (Fig. 2). Inspection of the map so obtained likewise reveals the gradual eastward sinking of the fluvial series and the simultaneous increase in thickness of the overlying aeolian deposits. The maximum thickness of these latter occurs slightly to the east of the present-day watershed. From the Tisza Valley region there advance into this series several tongues of riverlaid deposits wedging out towards the west. The heavy dashed line in the figure indicates the western limit of the Tiszian deposits.

According to the loess studies of I. MIHÁLTZ (1952), pollen analyses by M. FARAGÓ (1953) and A. HORVÁTH's Gastropod studies (1952, 1963) this thick aeolian sequence comprises the entire Pleistocene or at least most of it, excepting its lowermost parts. Accordingly, the deposition by the Danube in the area between the Danube and the Tisza must have ceased by the end of the lower Pleistocene at the latest. Fossil and heavy mineral studies (M. SZÉLES 1963 and B. MOLNÁR 1965, respectively) have established the lower limit of the Danubian sediments to coincide in the southern part of the region with the top of the upper Pannonian; the Danube-laid waste consequently fills out the whole upper Pliocene (Levantian).

Fig. 3 represents (on the basis of the author's studies) the percentage distribution of the heavy mineral species occurring in the contemporary waste of the largest Alföld rivers. The minerals diagnostic of the Danube and its tributaries are diopside, large grains of garnet, calcite and dolomite as well as tremolite, actinolite and disthene, not shown in the figure. The waste carried by the Tisza and its tributaries is distinguished by magmatic minerals (mostly derived from the Tertiary intra-Carpathian volcanic chain) such as hypersthene, augite and brown amphibole and these occur jointly with those mentioned earlier are particularly abundant in the rivers of the southeastern Alföld and are relatively poor in garnet calcite and dolomite and are relatively rich in limonite.

The information gained by the study of the heavy mineral assemblage of the Recent rivers has been useful in predicting the area of origin of the waste and the directions of transport for a given area of deposition of the Quaternary deposits (E. SZÁDECZKY-KARDOSS 1932). The results are shown in Fig. 4 for the northern, in Fig. 5 for the southern part of the area east of the Tisza, respectively. In the northern part, on the plateau of the Hajdúság, the Pan-

nonian is fairly near the surface, in a structurally elevated position as related to its surroundings (JASKÓ 1947, ERDÉLYI 1955, RÓNAI 1961, URBANCSEK 1962). This is why the drilling at Macs, located on top of the highest, central part of the area, encountered only the upper Pleistocene deposits. In the upper Pliocene (Levantine) and the lower Pleistocene the area was a slightly uplifted watershed (ERDÉLYI 1955). In all three drillings of the profile, the fluvial deposits have been found to derive from the Tisza and her tributaries which in the period in question constituted a centrifugal system of drainage in the region.

The composition of the underlying deposits is different and also the heavy minerals of the Macs and Kemecse borehole profiles exhibit certain differences at this lower level. The Hajdúnánás drilling, having traversed deposits of a finer grain size, could not be investigated by the above-outlined methods. This deeper assemblage of varied but mostly metamorphic minerals presumably indicates the uppermost part of the Pannonian. The area of derivation of the minerals has not yet been established. A third horizon abounding in brown amphibole is due to the reworking of some of the younger Tertiary volcanics of the broader neighbourhood (KŐRÖSSY 1957, 1964).

In the southern part of the Tiszántúl (Fig. 5), the lower limit of the Quaternary is not yet satisfactorily established; the investigated deposits do presumably not represent more than a fraction of the Quaternary (KRETZOI 1953); in the area, the thickness of the fluvial deposits is much greater than in the foregoing one.

To the depth that has been disclosed by the Fábiánsebestyén—Eperjes profile of drillings (Fig. 5), there occur two well-defined heavy mineral assemblages; the upper one exhibits also in this case a marked affinity to the Tisza drainage area, being rich in pyroxenes (mostly hypersthene and augite) and brown amphibole, containing besides smaller amounts of garnet, magnetite and bluish-green amphibole together with apatite, tourmaline, actinolite, tremolite, disthene, staurolite and limonite in traces. The assemblage of the deeper horizon is characterized by the absence or scarcity of hypersthene and by the reduced amount of augite and brown amphibole. Of the metamorphic minerals garnet, bluish-green amphibole and chlorite are slightly enriched.

On the basis of the above-said we can distinguish in the Alföld the following regional units, horizons and areas of drainage in the Quaternary and in the immediate pre-Quaternary.

1. A western area of predominantly Alpine (mainly metamorphic) waste, with diopside, large grains of garnet, bluish-green amphibole, calcite, dolomite and smaller amounts of metamorphic minerals such as chlorite, tourmaline, epidote, zoisite, tremolite, actinolite, staurolite, disthene. Hypersthene and augite are subordinate. The deposits characterized by this assemblage were

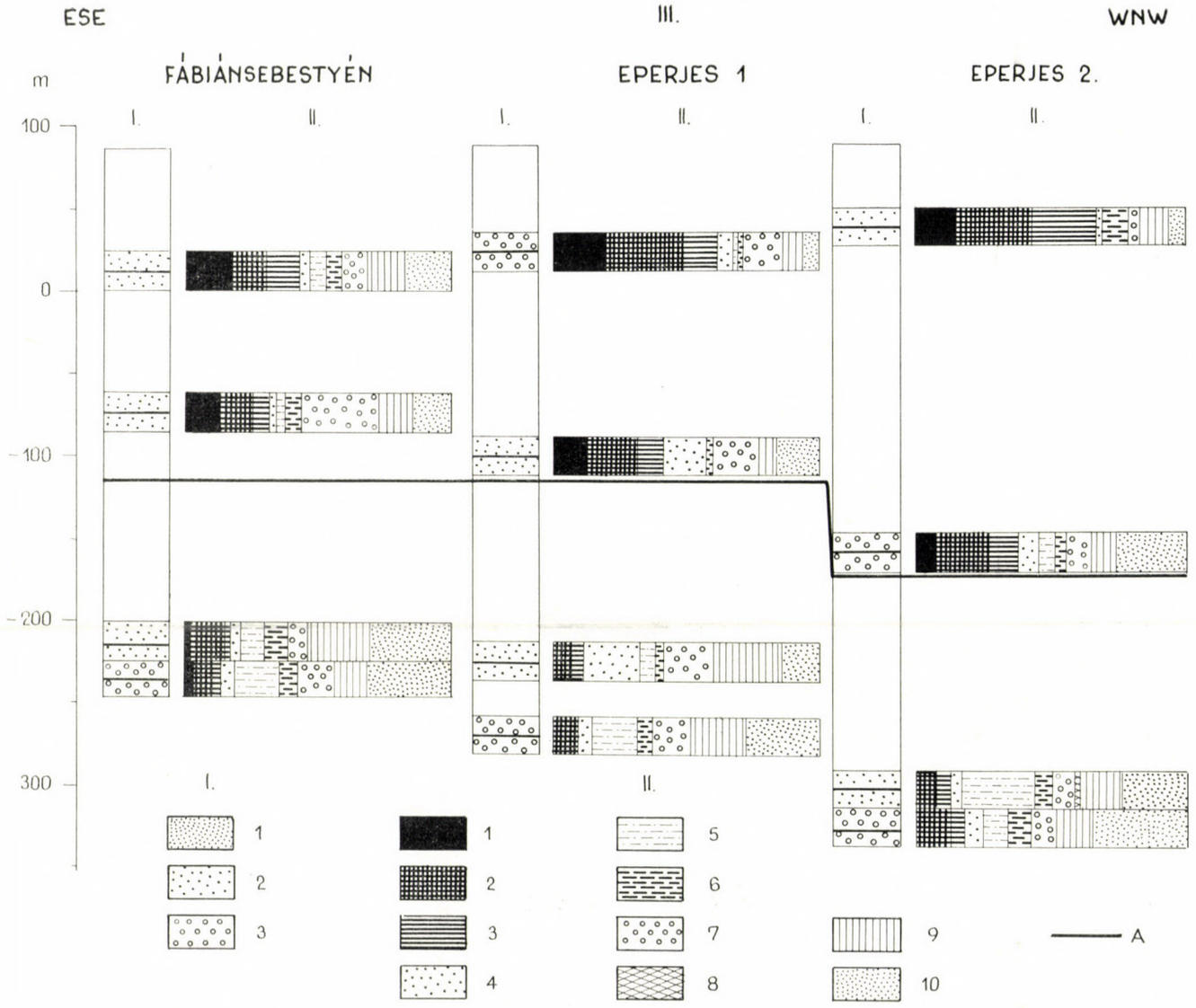

Fig. 5. A profile across the southern Tiszántúl. I. Grain size distribution: 1. — superfine sand (0.06—0.1 mm), 2. — fine sand (0.1—0.2 mm), 3. — medium sand (0.2—0.5 mm)
II. Heavy mineral distribution. 1. — Hypersthene, 2. — Other pyroxenes (predominantly augite). 3. — Brown amphibole. 4. — Magnetite. 5. — Chlorite. 6. — Bluish-green amphibole. 7. — Garnet. 8. — Calcite, dolomite. 9. — Rest of the mineral species. 10. — Decomposed grains.
III. Limits: The lower limit of the deposits of Tiszian derivation

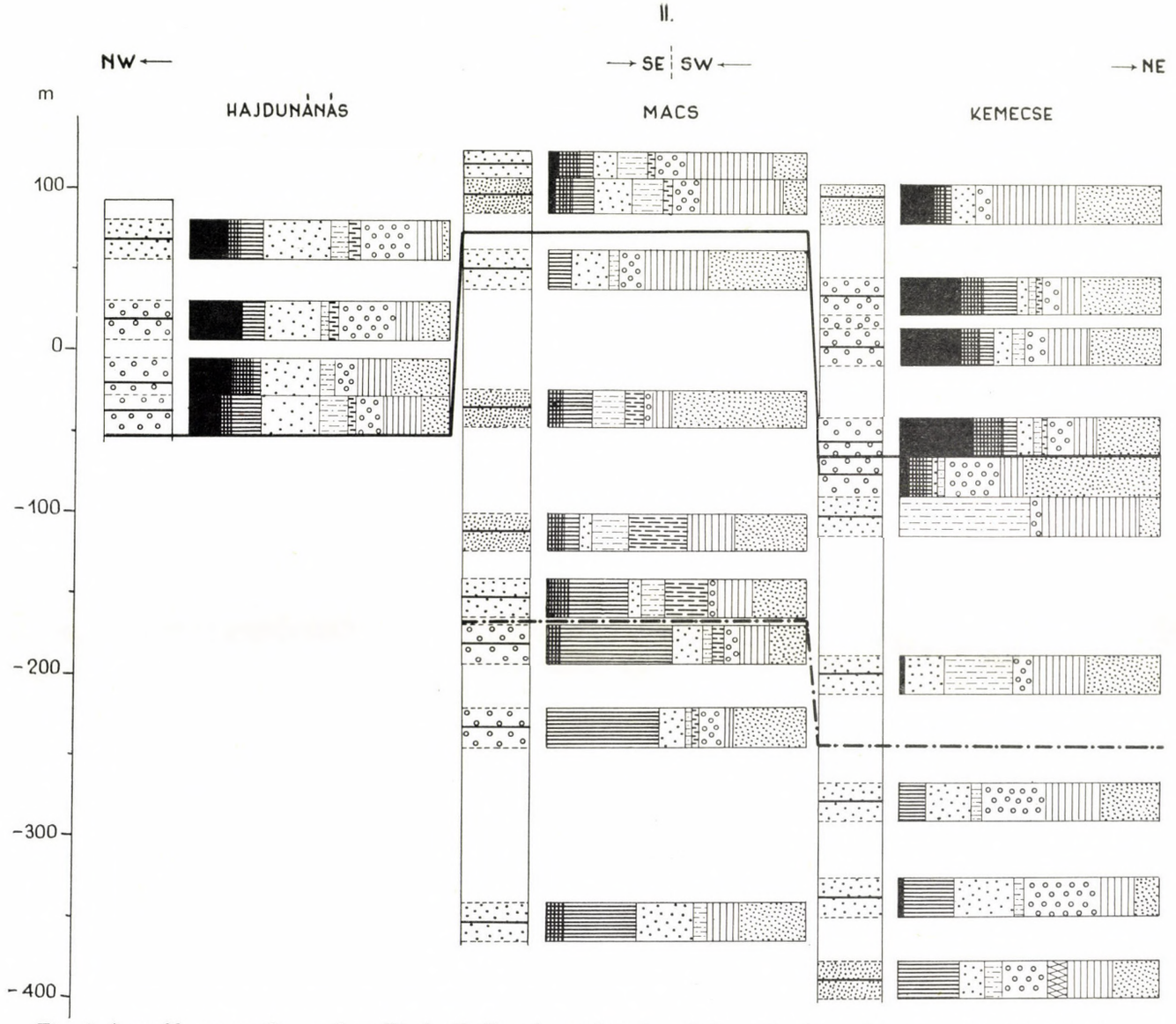

Fig. 4. A profile across the northern Tiszántúl. For the explanation of the grain size and heavy mineral distribution see, *Fig. 5.* Limits: 1. — Lower limit of the Pleistocene and of the deposits of Tiszian derivation. 2. — Limit of the horizon rich in metamorphic minerals and brown amphibole (upper Pannonian)

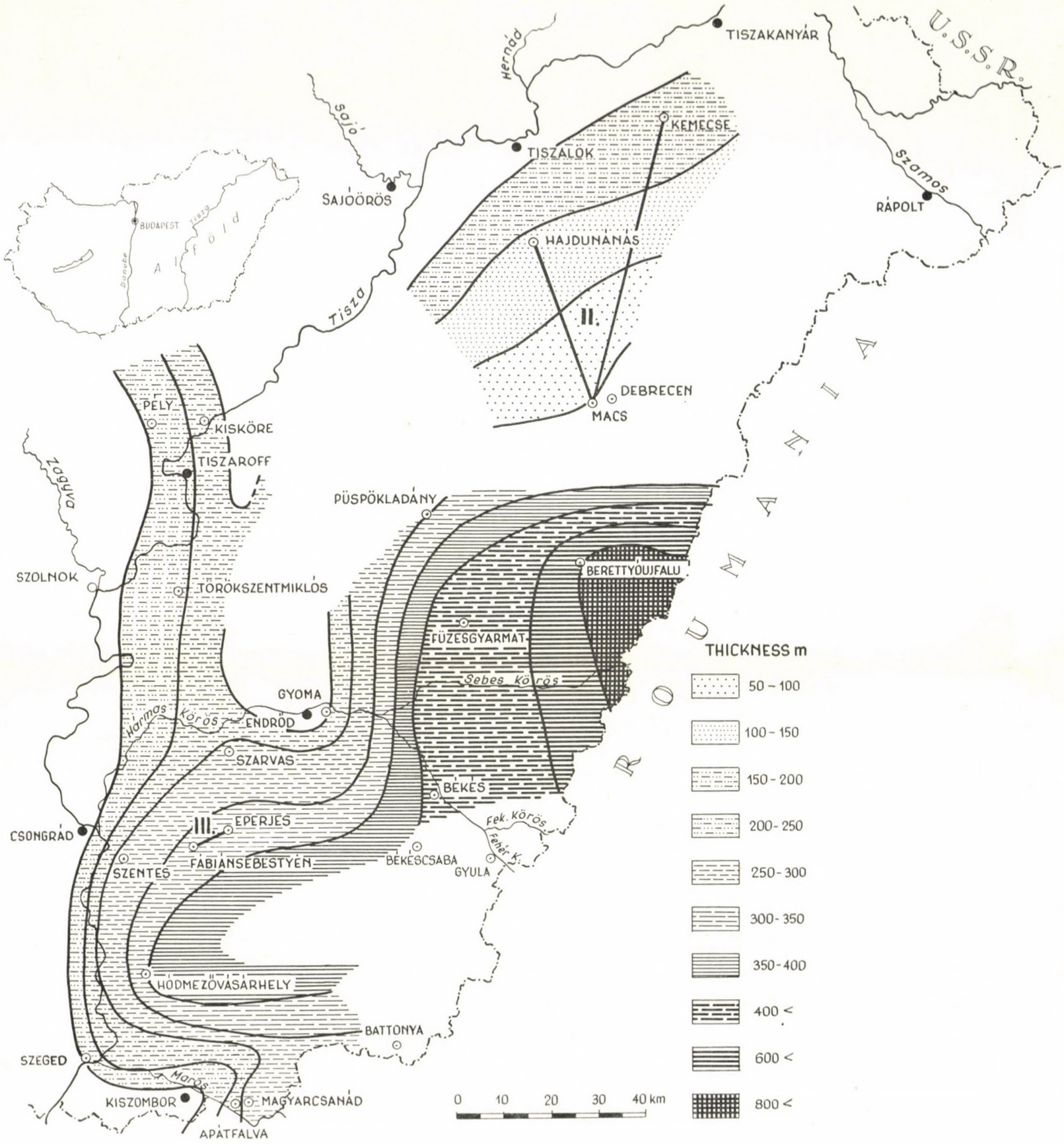

Fig. 6. Isopach map of the deposits of Tiszian derivation. (For the explanation of the indicated localities see Fig. 2.)

deposited by the Danube in the uppermost Pliocene and in the lower Pleistocene, having subsequently been blown out of the floodplain by the wind and laid down in the form of aeolian sands on the watershed between Danube and Tisza.

2. In the area of drainage and deposition of the Tisza the influence of the intra-Carpathian volcanic chain is clearly seen. The characteristic assemblage is composed of hypersthene, augite and brown amphibole. These deposits were laid down in the course of the Pleistocene on the Tiszántúl and in the northern part of the land between Danube and Tisza by the Tisza and its tributaries (MOLNÁR 1965).

3. In the northern Tiszántúl the upper horizons of the upper Pannonian brackish series exhibit a varied but predominantly metamorphic heavy mineral assemblage.

4. The fluvial deposits underlying the layers of Tiszian derivation in the southern Tiszántúl are characterized by the absence or diminished abundance of hypersthene, augite and brown amphibole. Of the metamorphic minerals, garnet, chlorite and bluish-green amphibole are enriched. The sequence must have been derived from an area far beyond the intra-Carpathian volcanic range. The deposits were laid down by some precursor of the Recent rivers of the southern Tiszántúl. They are presumed to be of a lower Pleistocene or even of an older age.

On the basis of the available data we can construct the isopach map of the deposits laid down by the Tisza and its tributaries for most of the Tiszántúl, the deposits in question being encountered in most of the boreholes sunk in the area (Fig. 6). The map reveals the deposits to be the thinnest (of not more than 50 metres thickness) in the uplifted area of the Hajdúság around Macs. The thickness of the series increases thence towards the Tisza valley, attaining a thickness of 170 metres at Kemecse. In the western part of the Tiszántúl it further thickens, first in a direction parallel to the Tisza valley, and thence towards the east, gradually approaching a value of 250 metres. Around Gyoma the series becomes thinner again, only to reach its maximum thickness further east, in the Körös Rivers plain. Near the border it exceeds 800 metres.

The isopach maps of the aeolian and Tiszian fluvial deposits (Figs. 2 and 6) reflect on the one hand the influence of the basement, and the Quaternary crustal movements of the Alföld, on the other. According to the isopachs of the aeolian deposits, the maximum thickness of these latter, which exceeds 140 metres, occurs in the southern part of the land between the Danube and the Tisza. The variation in the thickness of the aeolian deposits suggests a faster rate of sinking in the east than that in the west. On the right bank of the Danube the Pannonian is still on the surface (ERDÉLYI 1960, PÉCSI 1959), whereas the sole outcrop on the left bank is that of the Solt hummock. Thence

the Pannonian gradually sinks to deeper levels towards the east. The NE—SW structure which is apparent around Felsőszentiván implies a relatively elevated portion of the basement having this same general strike (CSIKY 1963). Near the Tisza line (Fig. 1) Tiszian fluvial deposits occur between the aeolian layers. The alternation of the two types of deposits is supposed to have been governed by the rate of sinking: slower rate — aeolian accumulation, faster rate — Tiszian fluvial deposition, respectively.

Very thin Tiszian sediments of the Hajdúság (Macs) reflect the lack of the lower Pleistocene and the upper Pliocene (Levantine), that is, an uplift of the area during that period (ERDÉLYI 1960).

Thick deposits in the Körös Rivers region indicate it to be one of the fastest-sinking part of the Alföld (KERTAI 1957, KŐRÖSSY 1963, BARTHA 1959).

REFERENCES

BARTHA, F.: MÁFI Évi Jelentése 1959-ről, 271—295, 1962. — BULLA, B.: Földrajzi Könyv- és Térképtár Értesítője **2,** 10—12, 1951. — BULLA, B.: Az Alföld felszínének kialakulása. (Evolution of the surface of the Alföld [Hungarian Plains]). Alföldi Kongresszus kiadványa. Akadémiai Kiadó, Budapest, 1953. — BULLA, B.: Magyarország természeti földrajza. (Physiogeographie von Ungarn.) Tankönyvkiadó, Budapest, 1962. — CAILLEUX, A.: Geologische Rundschau **40,** 11—19, 1952. — CSIKY, G.: Földrajzi Közlemények **11,** 19—35, 1963. — DÁVID, P.: A Duna—Tisza közi futóhomok koptatottsága. (Rolledness of the aeolian sands in the land between the Danube and the Tisza.) (Manuscript.) 1955. — ERDÉLYI, M.: Hidrológiai Közlöny **35,** 159—169, 1955. — ERDÉLYI, M.: Hidrológiai Közlöny, **40,** 90—105, 1960. — ERDÉLYI, M.: Földrajzi Értesítő **9,** 257—276, 1960. — FRANYÓ, F.: Magyar Állami Földtani Intézet Évi Jelentése 1961-ről, 31—46, 1961. — HORVÁTH, A.—ANTALFI, S.: Annales Biol. Hung. **2,** 417—428, 1952. — HORVÁTH, A.: Acta Biologica Szegediensis **9,** 102—115, 1963. — JASKÓ, S.: Földtani Közlöny **77,** 26—36, 1947. — KERTAI, GY.: Földtani Közlöny **87,** 383—394, 1957. — KRETZOI, M.: A negyedkor taglalása gerinces fauna alapján. (Subdivision of the Quaternary on the basis of the Vertebrate fauna.) Alföldi Kongresszus Kiadványa. Akadémiai Kiadó, Budapest, 1953. — KRIVÁN, P.: Acta Geol. Hung. **2,** 67—79, 1953. — KŐRÖSSY, L.: Bányászati Lapok **90,** 491—503, 1957. — KŐRÖSSY, L.: Földtani Közlöny **93,** 153—172, 1963. — KŐRÖSSY, L.: Földtani Közlöny **86,** 390—402, 1956. — MIHÁLTZ, I.: A Duna—Tisza csatorna geológiai viszonyainak tanulmányozása. (Study of the geological conditions of the trace of the Danube—Tisza canal.) *In :* A Duna—Tisza csatorna. Földm. Min. Kiadványa, Budapest 3—12, 1947. — MIHÁLTZ, I.: Magyar Állami Földtani Intézet Évi Jelentése 1950-ről, 113—144, 1953. — MIHÁLTZ, I.: Acta Geologica **2,** 109—120, 1953. — MIHÁLTZ, I.—UNGÁR, T.: Földtani Közlöny, **84,** 17—28, 1954. — MOLNÁR, B.: Földtani Közlöny **91,** 300—315, 1961. — MOLNÁR, B.: Acta Univ. Szegediensis, Acta Miner.-Petr. **15,** 43—51, 1962. — MOLNÁR, B.: Geologische Rundschau **53,** 848—866, 1964. — MOLNÁR, B.: Acta Univ. Szegediensis, Acta Min.-Petr. **17,** 69—88, 1964. — MOLNÁR, B.: Földtani Közlöny, 1965. (In press.) — MOLNÁR, B.: Hidrológiai Közlöny 1965. (In press.) — MOLNÁR, B.: Hidrológiai Közlöny 1965. (In press.) — PETTIJOHN, F. J.: Sedimentary rocks. Harper and Brothers, New York, 1957. — PÉCSI, M.: A magyarországi Dunavölgy kialakulása és felszínalaktana. (Evolution and relief of the Hungarian section of the Danube valley.) Akadémiai Kiadó, Budapest, 1959. — RÓNAI, A.: Magyar Állami Földtani Intézet Évi Jelentése 1956-ról, 299—316, 1959. — RÓNAI, A.: Magyar Állami Földtani Intézet Évi Jelentése 1961-ről, 19—30, 1964. — RÓNAI, A.: Magyar Állami Földtani Intézet Évi Jelentése 1961-ről. 5—17, 1964. — RUSSEL, R. D.—TAYLOR, R. E.: Journ. Geol. **45,** 225—267, 1937. — SCHERF, E.: Versuch einer Einteilung des ungarischen Pleistozäns auf moderner polyglazialistischer Grundlage. Verhandl. d. III. INQUA-Konferenz, Wien, 1936. — SCHNEIDERHÖHN, P.: Heidelb. Beitr. Miner. Petr. **4,** 177—191, 1954. — SÜMEGHY, J.: A Tiszántúl. (Die Gegend links der Theiss.) Magyar tájak földtani leírása. Budapest, 1944. — SÜMEGHY, J.: Magyar Állami Földtani Intézet Évi Jelentése

1950-ről, 233—263, 1953. — Szádeczky-Kardoss, E.: Mitt. d. berg- und hüttenm. Abt. Sopron, 1—38, 1932. — Széles, M.: Felsőpliocén tarka agyagok az alföldi szénhidrogénkutató fúrásokból. (Upper Pliocene mottled clays from the hydrocarbon-prospecting wells of the Hungarian Plains.) 1963. (Manuscript.) — Treitz, P.: Szeged és Kistelek vidéke. (The environs of Szeged and Kistelek.) Magyarázatok az agrogeológiai térképekhez. Budapest, 1905. — Urbancsek, J.: Szolnok megye vízföldtana és vízellátása. (Hydrogeology and water supply of Szolnok Country.) A Szolnok megyei tanács Végrehajtó Bizottságának kiadása. Szolnok, 1962. — Urbancsek, J.: Földrajzi Értesítő **12**, 1—34, 1963.

ОСАДОЧНО-ПЕТРОГРАФИЧЕСКОЕ И ГЕОЛОГИЧЕСКОЕ ИЗУЧЕНИЕ ЧЕТВЕРТИЧНЫХ ОТЛОЖЕНИЙ ВЕНГЕРСКОГО БАССЕЙНА (БОЛЬШОЙ ВЕНГЕРСКОЙ НИЗМЕННОСТИ)

Б. МОЛЬНАР

Резюме

В пределах Большой Венгерской Низменности можно выделить две зоны четвертичных отложений — междуречье Дуная и Тиссы, отличающееся развитием мощных эоловых осадков, с одной стороны, и Затиссье, слагаемое преимущественно речными наносами, с другой (рис. 2—6).

На междуречье Дуная и Тиссы путем изучения формы зерен можно определить мощность и распространение эоловых осадков (рис. 1—2). Изучение состава тяжелых минералов современных речных наносов позволяет в свою очередь разделить отложения обеих рек — т. е. Дуная и Тиссы — или их притоков (рис. 3). Таким образом, на основании результатов анализа тяжелых минералов в значительной части Затисья можно выделить на карте изолинии мощностей четвертичных отложений Тиссы и ее притоков (рис. 4, 5 и 6).

Среди эоловых осадков, выдутых ветрами с территории междуречья Дуная и Тиссы и с поймы Дуная, наблюдается ряд прослоев, слагаемых речными осадками Тиссы, которые к западу выклиниваются между эоловыми слоями. Карта мощностей эоловых осадков и речных осадков Притиссья (осадков Тиссы и ее притоков) отражает влияние палеомезозойского фундамента, с одной стороны, и следы движений земной коры в четвертичное время, с другой.

GENETIC CLASSIFICATION OF THE DEPOSITS CONSTITUTING THE LOESS PROFILES OF HUNGARY

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Observations concerning the packs of loess and fossil soils occurring in several upper Pleistocene profiles indicate that the formation of the individual packs of deposits took a time considerably shorter than hitherto believed. The evolution of a fossil soil or even of an entire fossil soil complex may not be attributed unconditionally to the full duration of an interglacial or interstadial phase. Furthermore, only a part of the loess packs occurring in the individual loess profiles is of primary aeolian origin. In the hills and mountains deluvial — stratified — varieties of loess prevailed and on the low-lying alluvial fans — the ancient floodplains of the rivers — fluvial deposition was dominant.

In the loess profiles of the Carpathian Basin, the polygenetic accumulation of a vertical sequence of various types of loesses can be proved. The aeolian deposition *in situ* is not as ubiquitous as was heretofore believed and the deluvial, proluvial, fluvial and eluvial deposits were at least equally widespread. A detailed genetic classification of these types is given in Table 4.

The genetic classification of the continental deposits and soils constituting the loess profiles of the Pleistocene, the establishing of their sequence of deposition and the determination of their probable conditions of origin is indispensable for any further and more comprehensive study into Pleistocene geology or geochronology, whether it is of palaeontologic, palaeobotanic, archaeologic or palaeopedologic nature in its principal orientation. In the past the microstratigraphic and palaeopedologic study of the Hungarian loess profiles was restricted almost entirely to the Paks profile (ÁDÁM—MAROSI—SZILÁRD 1954, P. KRIVÁN 1955, STEFANOVITS—RÓZSAVÖLGYI 1962, etc.).

Of late, the present author has made an attempt at the reconstruction of the depositional rhythms of the slope loesses on the basis of terrace and slope morphology, periglacial ground frost phenomena, loess genesis and the texture and structure of the deposits (PÉCSI 1961, 1962). This analysis was directed in the first place towards establishing the sequence of deposits occurring between two zones of fossil soil (Fig. 1). In case there occur several such fossil soil zones in the profile, the sequence of the interbedded deposits between the individual soil horizons may vary even within the same profile. On the other hand, soils of different origin and various types of loess might be observed to substitute each other in the sequence.

After having examined every loess profile of some importance within the Carpathian Basin, the author has distinguished the following phenomena and types of deposits.

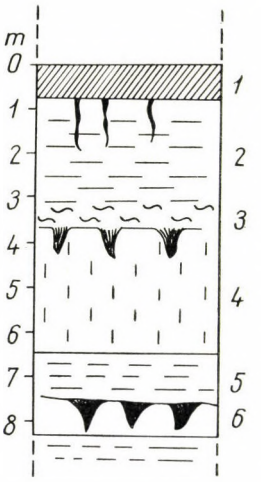


Fig. 1. Generalized profile of the phases of slope deposit formation between two fossil soil horizons of the last glaciation (PÉCSI, 1962). 1 — fossil steppe soil — chernosem — from whose lower part a polygonal pattern of lime-filled cracks extends down to a depth of 1.5 to 2 m. 2 — rhythmically stratified slope loess or sandy loess. Sediment deposited out of the slopewash. Little precipitation in early summer, considerable amount of snow, periodically frozen subsoil. 3 — finely stratified slope loess, with a slightly cryoturbated structure. Deposited by solifluction in the course of a wet cold atlantic spell of climate. 4 — unstratified, typical loess. Deposited out of the air in the driest, coldest spell of the continental stadial climate. 5 — stratified slope loess, substituted locally by likewise stratified loessy slopewash soil (loessy semipedolite). The deposition occurred by pluvionivational slopewash at the beginning phase of the stadial. 6 — fossil forest soil (or wooded steppe soil). Developed under a warm humid forest climate. The forest was exterminated by the gradual cooling of the climate. In the upper part of the forest soil traces of cryoturbation are locally observed.

1. Unstratified loess packs* (aeolian accumulation)

a) The deposits mentioned in literature under the heads "typical loess", "true loess", "aeolian loess", meaning unstratified packs of loess, do not constitute in general more than one third of the loess profile (Figs. 2, 3, 4, 5). Similar profiles have lately been described by KUKLA (1961), LOŽEK (1964), STEFANOVITS—RÓZSAVÖLGYI (1962), REMY (1960) and by GÜNTHER (1961).

b) The packs of unstratified loess are frequently substituted by unstratified sandy loess, differing only as to its grain size distribution from the above type.

The maximum thickness of the unstratified loess packs is generally less than 5 metres, being mostly about 1.5 to 4.0 m. The thicker packs of 4 to

* The term "pack" is intended to signify a number of adjacent layers, of more or less homogeneous lithology, deposited on dry land.

5 metres are bound to occur near the top of the profile (maximum of the Würm). Their physico-chemical properties, mineralogical composition, etc., are listed in Tables 1, 2 and 3.

These deposits presumably consist largely of aeolian dust. They were observed to contain in some profiles local intercalations of tuffite (KRIVÁN—RÓZSAVÖLGYI 1962, 1964). In this type of loess the percentage of biotite among the heavy minerals also may be rather high locally (30 to 50 percent). This type of deposit has been a subject of a great deal of controversy as mere lack of stratification is not an irrefutable proof for pure aeolian origin.*

In the upper Pleistocene loess profiles the number of unstratified loess packs varies from 2 to 5.

2. Stratified slope loesses and loesslike slope deposists (Deluvial accumulation)

a) The homogeneous type of stratified loess forms thin layers of 1 to 15 mm thickness readily visible even to the naked eye. Their dip (3 to 15°) is generally the same as the slope of the Recent relief. Sometimes, however, they follow the contours of valleys and dells filled up since. Although the deposits of stratified slope loess locally present a highly homogeneous aspect, the thin layers that can be taken apart in the original humid state of the substance are sometimes of markedly different grain size distribution. The aeolian dust fraction (0.02 to 0.05 mm) seldom exceeds 45 percent, and the sandy or clayey fraction or both may attain considerable importance (Tables 1, 2, 3). On the periphery of the basin where precipitation was more abundant, particularly in the western part of the Transdanubian hummocks up to the eastern foothills of the Alps, the clayey fraction is gradually enriched: stratified loess thus grades into a kind of adobe (stratified clayey loess). In the case of these marginal facies the difference in grain size distribution of the fine sandy and clayey strata becomes more pronounced.

This relatively homogeneous variety of stratified slope loess is called hummock loess.

b) As opposed to the above subtype, the piedmont and foothill slopes of the Hungarian Mountains exhibit a heterogeneous type of stratified slope loess. The packs consisting of thin layers of loess and loess-like deposits are rhytmically intercalated by layers of rock detritus. The detritus gradually grows finer with increasing distance from the mountains and the number

* In the grain size distribution of this type of loess the 0.02 to 0.05 mm fraction represents 45 to 60 percent by weight. The grains are encrusted by lime. The carbonate content is 20 to 25 percent, which includes some $MgCO_3$. The CO_2 content is 15 to 20 percent. Porosity is 50 to 55 percent, against that of clayey loamy loess (35 to 45 percent) and of sandy loess (60 percent) (I. LÁNYI-MIHÁLYI 1953, L. MOLDVAY 1962, I. MIHÁLTZ 1953, A. RÓNAI 1961, T. UNGÁR 1964).

Table 1

a) *Mean grain size distribution of unstratified aeolian loess in percent*
(I. MIHÁLYI—LÁNYI, analyst)

Sampling site	Number of averaged samples	Grain size distribution (percent)									
		under 0.002 mm	0.002—0.005 mm	0.005—0.01 mm	0.01—0.02 mm	0.02—0.05 mm	0.05—0.1 mm	0.1—0.2 mm	0.2—0.5 mm	above 0.5— mm	total
1. Paks, brickyard 16.10—19.40 m	16	2.9	3.1	4.7	15.2	49.7	20.6	0.9	0.4	0.0	97.5
2. Paks, brickyard 24.7—24.9 m	1	5.3	3.6	5.2	13.1	53.2	16.1	0.6	0.2	0.0	97.3
3. Mende, brickyard 12.5—13 m	1	9.3	5.1	5.8	14.3	44.6	16.1	0.6	0.0	0.0	95.8
4. Mende, brickyard 15.8—18 m	4	12.8	4.6	7.1	19.6	44.0	9.1	1.4	0.0	0.0	98.6

b) *Grain size distribution of stratified slope loess in percent*
(I. MIHÁLYI—LÁNYI, analyst)

Sampling site	Grain size distribution (percent)									$CaCO_3$ content percent
	under 0.002 mm	0.002—0.005 mm	0.005—0.01 mm	0.01—0.02 mm	0.02—0.05 mm	0.05—0.1 mm	0.1—0.2 mm	0.2—0.5 mm	above 0.5 mm	total	
1. Paks, brickyard cca 8.5 m	7.7	6.8	17.5	14.3	44.6	7.4	0.9	0.3	0.0	99.5	16.69
2. Paks, brickyard cca 38 m.....	7.3	9.1	9.0	18.6	36.6	14.3	1.5	0.6	0.4	97.4	6.11
3. Mende, brickyard 7.60 m	15.9	9.1	10.8	16.1	36.9	6.6	3.0	0.0	0.0	98.4	15.87
4. Bakonybél basin	7.5	11.0	8.2	16.1	34.7	18.8	2.2	0.0	0.0	98.5	16.73

Table 2

Results of chemical analysis of loess (I. LÁNYI—MIHÁLYI, analyst)

Sampling site	SiO_2	FeO	Fe_2O_3	TiO_2	Al_2O_3	CaO	MgO	Ignition loss	Moisture ($-H_2O$)	MnO
	in percent									
A) Unstratified loess packs										
1. Mende, brickyard 12—12.5 m	45.68	0.75	1.77	0.28	5.48	16.82	4.60	19.28	0.82	0.07
2. Same, 12.5—13 m	49.36	0.85	2.34	0.39	8.28	14.58	4.96	16.14	0.29	0.09
3. Same, 24—24.5 m	41.32	0.35	2.45	0.35	6.70	17.38	5.38	19.58	0.25	0.07
B) Stratified loesses										
1. Paks, brickyard cca 8.5 m ..	56.94	1.11	2.00	0.36	9.02	12.75	3.48	12.08	0.34	0.09
2. Mende, brickyard 7.6 m	54.92	1.11	3.00	0.98	10.72	11.49	2.36	12.17	0.77	0.10
3. Mende, brickyard cca 29 m .	60.38	1.13	2.79	0.36	9.16	9.30	3.82	12.05	0.77	0.11
4. Bakonybél	57.10	1.07	3.10	0.36	10.02	8.41	4.10	10.33	0.33	0.11

Table 3

Heavy mineral distribution of loess (in percents of the number of grains) (I. LÁNYI—MIHÁLYI, analyst)

Sampling site	magnetite	biotite	amphibole	augite	enstatite	hypersthene	apatite	titanite	zircon	tourmaline	andalusite	disthene	epidote	zoisite	garnet	chlorite	tourmaline-bearing quartz	pyrite	limonite	leucoxene	total
A) Unstratified loess																					
1. Mende, brickyard 12—12.5 m	—	11	12	2	—	—	2	—	—	—	—	—	8	4	32	17	—	9	3	—	100
2. Mende, brickyard 12.5—13 m	—	30	12	—	—	—	1	—	—	—	1	2	7	—	16	24	—	2	5	—	100
3. Mende, brickyard 24—24.5 m	5	20	10	—	—	—	—	—	—	4	—	5	5	—	12	39	—	—	—	—	100
B) Stratified loess																					
1. Mende, brickyard cca 7.6 m	2	12	13	—	—	—	—	—	—	—	—	4	13	—	23	18	—	—	—	15	100
2. Mende, brickyard 29 m	—	10	16	—	—	1	—	1	—	2	5	5	10	—	26	13	—	—	11	—	100
3. Bakonybél	3	15	9	—	5	—	2	—	—	—	—	4	6	—	29	15	2	—	10	—	100

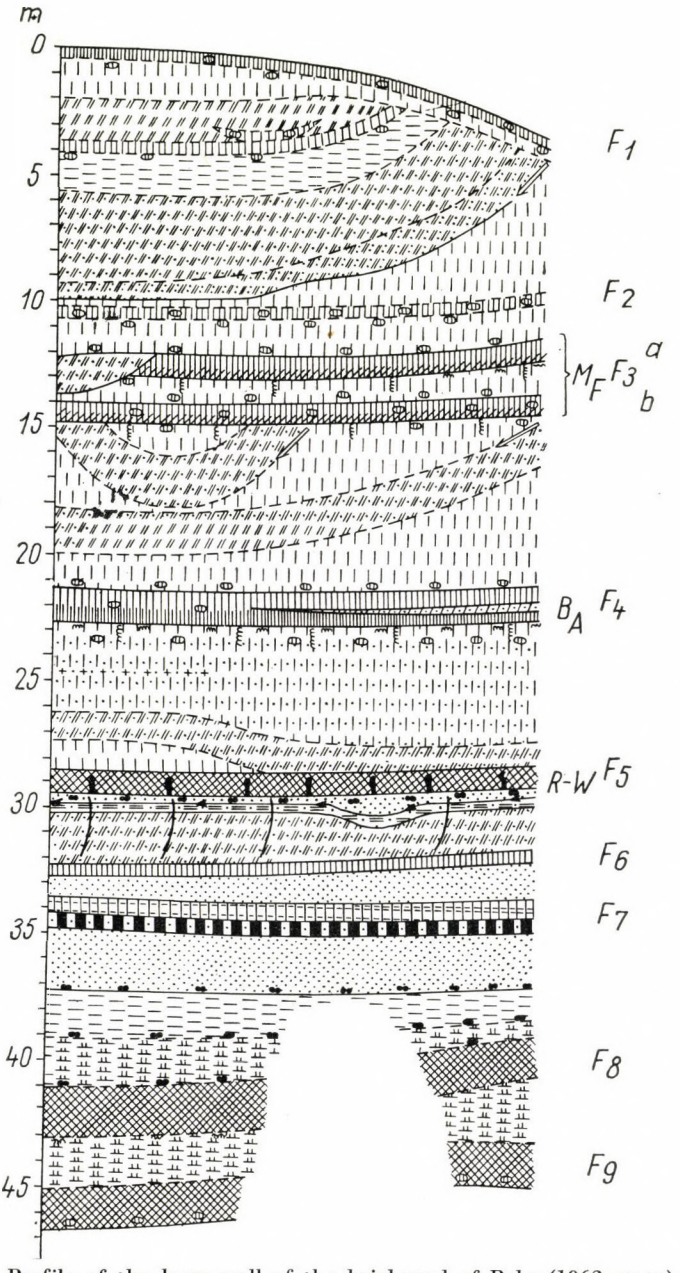
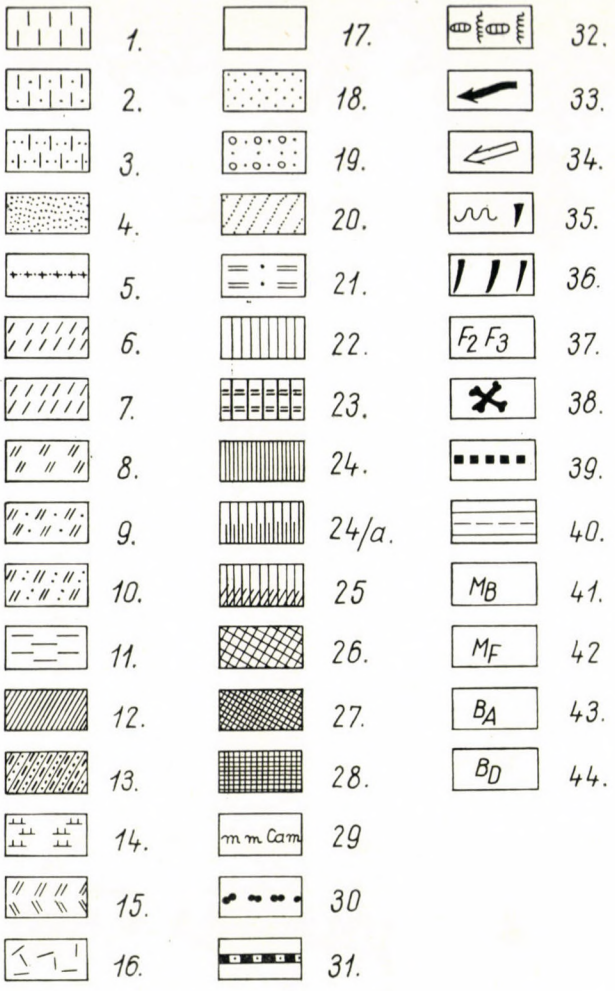


Fig. 2. Profile of the loess wall of the brickyard of Paks (1962 state)



Legend: *Fig. 2—7*

I. Predominantly aeolian deposits: 1. — unstratified true loess; 2. — sandy loess; 3. — loessy sand; 4. — wind-borne sand, fine sand; 5. — volcanic tuffite

II. Predominantly deluvial-eluvial deposits: 6. — slope loess; 7. — sandy slope loess; 8. — stratified slope loess; 9. — stratified sandy slope loess; 10. — stratified loessy sand; 11. — stratified clayey loess; 12. — loessy slopewash soil (loessy semipedolite); 13. — sandy, clayey slopewash soil

III. Altered loesses. 14. — clayey loess (adobe, loess loam, ancient loess); 15. — decalcified clayey loess; 16. — gleyified loess; 17. — loess pack in general, genesis not specified

IV. Fluvial-proluvial deposits: 18. — fluvial sand; 19. — fluvial sand and gravel; 20. — proluvial sand; 21. — sandy clay, clayey sand (mud, silt)

V. Recent and fossil soils, illuvial horizons of soils: 22. — slightly humified horizons; 23. — swamp and marsh soil; 24. — chernosem-type soils; 24/a. — chestnut soil (kastannosem) (?); 25. — chernosem-brown forest soil; 26. — brown earth; 27. — brown earth with clayey illuvium ("Parabraunerde"); 28. — red (clayey) soils; 29. — horizon of lime accumulation ("Kalkilluvialhorizont"); 30. — lime dolls; 31. — limy sandstone bank, layer of concretions; 32. animal burrows, wasp holes

VI. Miscellaneous: 33. — erosional hiatus; 34. — phase of derasion (dell scooping); 35. — features of cryoturbation, solifluction; 36. — desiccation cracks; 37. — fossil soil horizons and accumulation of humus; 38. — finds of vertebrate fossils; 39. —charred wood fragments; 40. — limits of the formations: *a*) well-defined, *b*) vague, *c*) unconformity; 41. — "basal soil complex of Mende"; 42. — "upper soil complex of Mende"; 43. — "lower soil complex of Basaharc"; 44. — "upper soil complex of Basaharc"

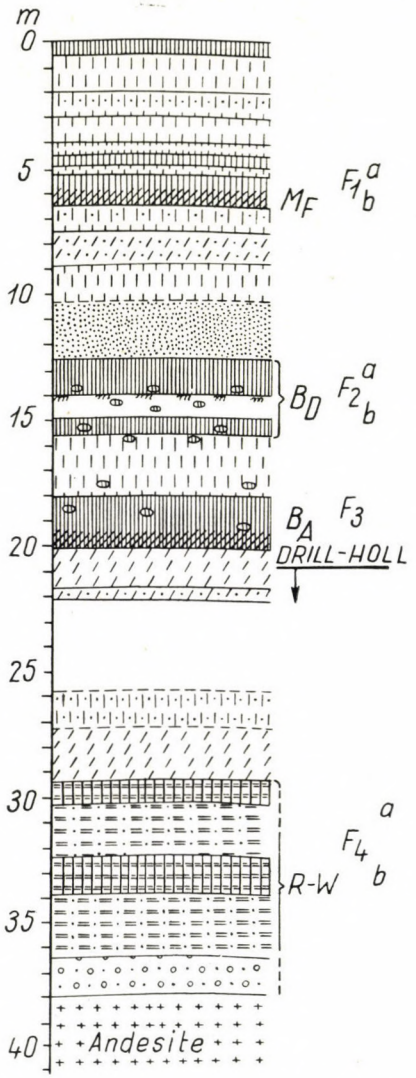


Fig. 3. Profile of the loess wall of the brickyard of Basaharc. The loessy series overlies the second terrace above the floodplain of the Danube

of detrital layers also diminishes. To the diverse regional types of stratified heterogeneous loess the author has given the comprehensive name of "mountain loess" (stratified slope loess with detritus). In the loess profiles of the mountains the packs of unstratified ("typical") loess play but a subordinate part.

The alternation and the proportions of stratified slope loess and unstratified "typical" loess within a given profile are determined by local as well as regional factors. Thus e.g. within a given area the slopes of southern exposure may be covered exclusively with stratified slope loess.

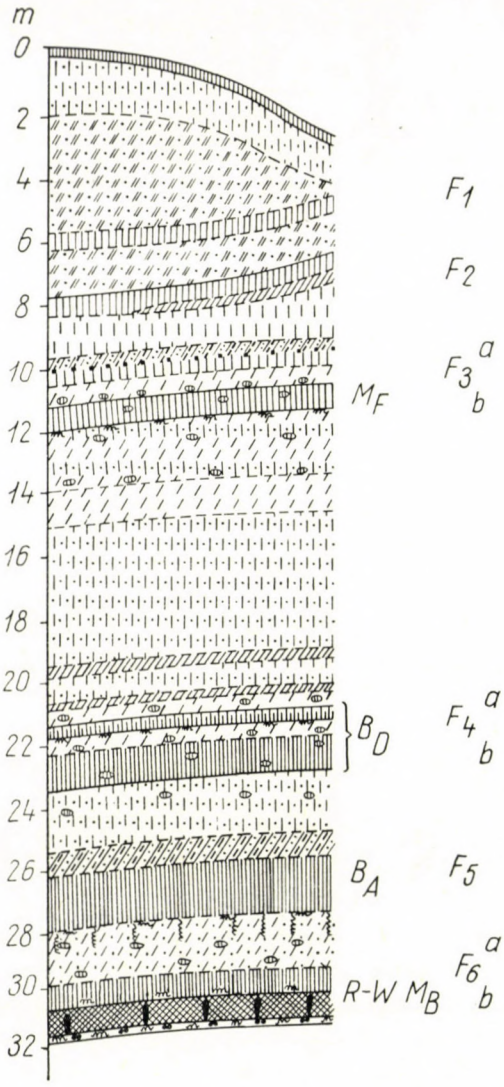


Fig. 4. Profile of the loess wall of the brickyard of Mende, 40 km SE of Budapest

c) The hummock and mountain subtypes of stratified slope loess occur in a number of varieties hard to tell apart. Some of them cannot even be classified as loesses any more, in which case they are to be termed loess-like slope deposits. This term comprises the loamy and clayey varieties on the one hand and the sandy varieties on the other.

A widespread type of stratified loess-like deposit is the loessy slope-wash soil (loessy soil sediment).

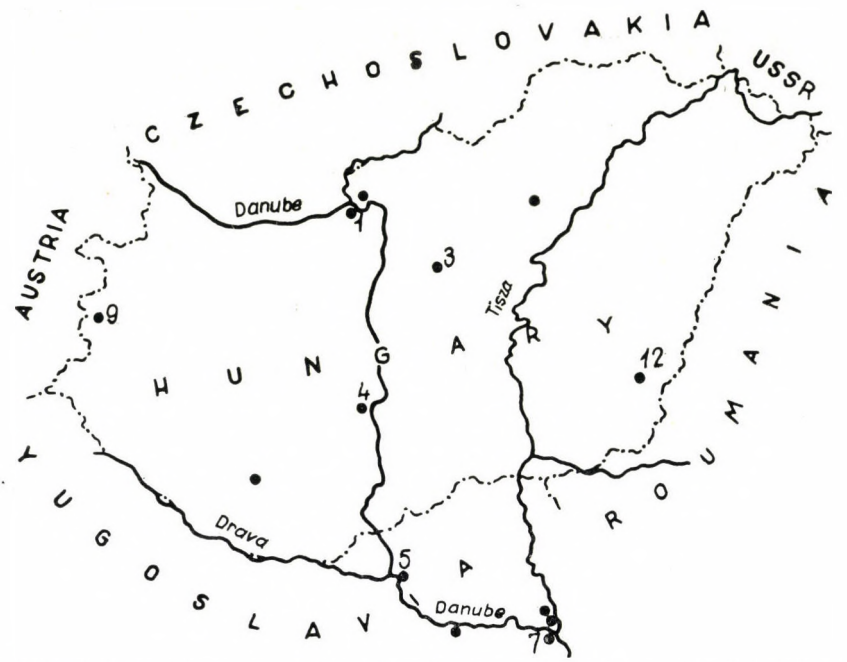


Fig. 5. Sketch map of the loess profiles. 1 — Basaharc, 3 — Mende, 4 — Paks, 5 — Erdut, 7 — Stari Slankamen, 9 — Szombathely, 12 — Békéscsaba

The abundance of reworked soil or humus in the slope deposits can be as high as to render the layers of loess or sandy loess wholly inconspicuous between the fine layers of slopewash soil. In this case we are dealing with a stratified slope sediment soil ("semipedolite" PÉCSI 1961, "Lehmbröckelsand" KUKLA 1961, LOŽEK 1964).

The geomorphologic, microstratigraphic and lithologic study of the stratified slope loesses and loess-like deposits reveals a deposition by meltwater and precipitation running in the form of slopewash over permanently or periodically frozen ground. Most of the accumulation must have taken place in the stadials as the stratified slope-loess packs frequently exhibit the traces of syngenetic cryoturbation. However, the cryoturbated forms do not warrant the conclusion that the climate was a uniformly humid and cold one. It seems that the transportation and deposition of the material was rather sluggish and intermittent, several interruptions being indicated by embryonal soils and phases of humification (Fig. 4).

3. Unstratified slope loesses and loess-like deposits, glacial loams

The subtypes of this group and their areal distributions recall those of the above group. A number of transitional types are known, from slope

loesses that appear practically homogeneous, to glacial loams that had lost most of the features they once had in common with loess.

a) *Unstratified slope loess* cannot in general be distinguished from unstratified aeolian loess except if thoroughly examined in the field and in the laboratory. The best indicator is the presence of diverse scattered inclusions in the loess pack, rock detritus of various size, pebbles, minute clods or bands of fossil soil, clayey, loamy or sandy lenticles of vague outlines offering irrefutable proof of a deluvial redeposition. The considerable scatter of the grain size distribution, the rather high percentage of humus and of organic matter at large, the compacted structure and the microscopic aspect of the sample serve as clues in the laboratory.

In certain instances it is apparent that slope loess, homogeneous at present, was stratified to start with and subsequently lost its stratification in the course of its diagenesis — a process whose intimate relationship with the overlying fossil or Recent soil horizon can readily be demonstrated locally.

b) The subgroup of *unstratified loess-like slope deposits* is very large. Also the genesis of the deposits belonging to this subgroup has been interpreted in a number of different ways. Some authors do not consider it as a loess type at all; others classify but a few of its varieties under the head of loess; others consider it as a reworked loess or, in the case of certain subtypes, as the mountain facies of loess.*

If the loess-like slope deposit contains irregularly distributed gravel or detritus of varied size, it is relegated to the subtype of slope loess with detritus (1). On the piedmont slopes of southerly exposure of the Hungarian Mountains there frequently occur slope loesses containing detritus mixed with fossil soil (2). On the more humid western periphery of the basin a loamy slope loess (3) occurs in vast patches.

In distinguishing the loesses and loess-like deposits of diverse derivation the physical and chemical laboratory methods have not proved satisfactory. In our opinion the decisive clues are to be expected from the three-dimensional microstratigraphic and structural analysis of the individual layers constituting the profile.

c) A rather widespread variety of *loamy slope loess* is *a glacial slope loam*, showing but very vague, if any, loess-like features. This variety too carries some detritus.**

* Based on his owon observations the present author calls "loess-like slope deposits" such deposits which contain a dust fraction not as high as that found in typical loess but still high enough (30 to 40 percent), a certain amount of $CaCO_3$, and feature a mineralogical composition resembling that of loess, a high porosity and forms of relief that could have developed on top of loess as well.

** This formation is a type reworked by slopewash of the Pleistocene deposit known by the names listed below: German, Staublehm (FINK), Russian, suglinok (MOSKVITIN, GERASSIMOV), Hungarian, nyirok (KEREKES), brown earth (SÜMEGHY) or glacial loam (BULLA).

d) The accumulation of the slope deposits in question in their present position is due — besides slopewash by precipitation and meltwater — in the first place to *periglacial slope solifluction* (PÉCSI 1961, 1962, 1964). Even in the past the clayey types of this group have been attributed in this country to solifluction and slopy-tundra phenomena (SZÁDECZKY-KARDOSS 1963, KEREKES 1941, BULLA 1939, 1960, PEJA 1959, SZÉKELY 1964 and many others). These deposits or packs of layers frequently exhibit traces of freeze-and-thaw solifluction, "Streifenböden", involutions and cryoturbated forms at large.

4. Epigenetically altered loesses

In the Carpathian Basin there occur in a considerable horizontal extent some loess types, repeatedly recurring in the profiles, certain features of which reveal them to be derived from loess by processes posterior to diagenesis. These types are frequently termed altered loesses. However, the concept and the phenomena it covers are interpreted in a variety of ways by various authors.

Not included in the concept of altered loesses are diverse regional facies of loess whose distinctive features are due to a diagenetic process essentially contemporaneous with their deposition, under a climate more humid than the typical steppe climate of loess deposition.

On the other hand, it seems justified to distinguish two types of loess epigenetically altered in the course of the pauses of loessification (= loessy diagenesis).

One group includes the altered loesses in the stricter sense — loess loams, adobes, grey reduced loesses, oxidized rusty loess packs, decalcified loesses, loess layers with lime dolls, and the so-called older loesses (Table 4). Their origin is connected with the chemical and physical processes induced by the movement of ground-water and precipitation as well as with the compacting effect of the overburden. No climatic control of this type of alteration is apparent.

The other group includes diverse types of soil interbedded in the loess profiles, the evolution of which is generally governed by a well-defined set of climatic conditions. The members of this group shall be treated in a separate section in view of their important stratigraphic role.

5. Fossil soils in the upper Pleistocene loess profiles

It is known that the interpretation as to pedogenetic type of the fossil soil horizons interbedded in the loess profiles is rather vague even if the most advanced procedures of soil analysis are applied. For this reason we shall

Table 4

Classification of the deposits composing the Pleistocene loess profiles of Hungary (PÉCSI 1965)

Geological-genetic classification	Petrographic classification Pedological classification of soils	Structure of the packs	Orographic, regional and climatic varieties of facies (syngenetic alterations)				Remarks
			Wet ground, Flood plain	Intrabasinal-plateau	Hummocks on the basin rim	Mountains-Piedmonts	
1	2	3	4	5	6	7	8
I. Aeolian							
1. Packs of loess	*a)* true loess (45—60 % rock flour of 0.02—0.05 mm ⌀)	unstratified,	partly aeolian "infused loess" (1) in the floodplains of alluvial fans (hydroaeolite) "Alföld" (Great Plains) loess (2)	unstratified "plateau loess" and certain packs of loess	in the W and N aeolian dust occurs in: "glacial loam" "brown earth" "Staublehm" (1)	partly aeolian dust deposit: "brown earth" "glacial loam" and a few loess packs	1) Local names given by various authors. Pelitic fraction may attain 30%; sand fraction also considerable (15—25%)
	b) sandy loess	porous					
	c) loessy sand	very porous, loose					
2. Sand, interbedded	*a)* loessy sand *b)* fine sand *c)* coarse sand	unstratified to stratified, very porous and loose	mostly local interbeddings in the loess packs, regional extension restricted to certain horizons and to the sand above the loess cover				(2) more or less sandy loess
3. Volcanic tuff	a) clayey tuffite with rock flour	unstratified porous	interbeddings of a few centimetres in the lower part of the upper Pleistocene series				
II. Fluvial							
1. Beds of fluvial loess (loess-like deposits)	*a)* clayey (silty) loess (rock flour) b) sandy "loess"	mostly stratified, plastic, slightly porous	"floodplain loess" "water loess" in part "hydroaeolite" ("infused loess")	local interbeddings between packs of loess			
2. Fluvial sands	*a)* clayey sand *b)* fine sand *c)* coarse sand	mostly stratified	frequent thin layers in floodplain loess	mostly local interbeddings between packs of loess, also regional extension in certain horizons			
3. Proluvial sands	*a)* unclassified sand *b)* sand with detritus	mostly of parallel stratification					
III. Deluvial (solifluction, slope wash)							* Thin layers parallel to the slope of homogeneous or heterogeneous grain size distribution in rhythmic alternation
1. Packs of slope loess	*a)* slope loess	unstratified / stratified* porous	occurring as "valley loess" on the bottom of minor valleys		"valley loess" redeposited: "glacial loam" "brown earth" and "Staublehm" "terra rossa" slope loess containing gravel and (dolomite) detritus		
	b) sandy slope loess	unstratified / stratified* very porous loose					
	c) clayey slope loess	unstratified / stratified* plastic porous					
	d) slope loess with detritus	unstratified / stratified* loose porous					
2. Packs of loess-like slope deposits *§*	*a)* sandy clay with rock flour — (sandy, loessy, clayey) slope deposit	each subgroup exhibits rhythmically stratified					*§* the pelitic fraction attains 30%
	b) loessy clayey slope deposit	as well as unstratified varieties,					
	c) loessy-clayey slope deposit with detritus	slightly porous					
3. Layers of semipedolite*** deluvial and colluvial varieties)	*a)* loessy semipedolite *b)* sandy-clayey semipedolite *c)* semipedolite with detritus *d)* humous semipedolite	rhythmically stratified or unstratified			mostly in dells (derasional valleys filled with slope loess) as interbeddings		***semipodolite = reworked soil mixed with loess and slope deposits
IV. Packs of eluvial loess	*a)* sandy loess *b)* clayey loess *c)* loess with detritus	unstratified porous	a cloak-like cover not thicker than 3 metres on top of diverse sandy-clayey deposits and under steppe-type soils			on top of massive rock on the lower piedmont surfaces: loess with sand, clay or detritus	
V. Organogenic	*a)* peat, muck *b)* clayey-boggy meadow soils *c)* sandy-boggy meadow soils		peat, muck (seldom) clayey-boggy meadow soils sandy-boggy meadow soils	scattered fragments of carbonized wood			
VI. Epigenetically altered loesses	*a)* argillized□ loess *b)* limeless loessy clay *c)* loess with lime concretions *d)* gleyified loess *e)* rusty gleyified loess *f)* compacted loess*	compact slightly porous, frequently plastic mostly unstratified	oxidation and reduction phenomena induced by ground water "gley loess", loess with lime concretions "meadow limestone" "lime mud"	adobe-like, loess layers, compacted loess,	limeless clayey loess or loessy clay under forest soils		□e.g. older loesses * compacted by overburden pressure, lime exsolution
VII. B horizons (illuvial zones) of fossil soils	*a)* pseudo-gley type forest soils				1. "pseudogley"	1. "pseudogley"	Horizons of lime accumulation due to pedogenesis, banks of limestone, mainly beneath red soils
	b) brown forest soils			1. brown earth 2. rust-brown forest-soil	1. brown earth. 2. „parabraunerde" 3. red (clay) soil		
	c) chernosem-type soils			1. chernosem soil 2. chestnut-brown soil (?) 3. chernosem-brown forest soil			
	d) meadow soil, alkali soil		meadow soil meadow chernosem alkali soil				
	e) skeletal soils		marsh soil alluvial meadow soil	brown illuvial horizons, adobe-like; not defined more specifically			
	f) weakly humous horizons			humous carbonate soils, humified horizons			
VIII. Periglacial ground frost phenomena			1. frost wedges 2. traces of ice laccoliths 3. cryoturbational disturbances ("Würgelboden")	1. polygonal ground fissures due to desiccation (Trockenriss)	2. soil wedges 3. striated soil (Streifenboden) 4. cryoturbated layers	1. stone pavement 2. ventifacts	Deposits accumulated by solifluction, part of the slope loesses and clayey slope loesses

restrict classification to the essential principal groups. The classification presented here is based on a thorough comparative study over a vast area.

The comparative studies in question have revealed the Pleistocene loess profiles of the Carpathian Basin to include a larger number of fossil soil horizons than their Austrian, Moravian, Czech, German or Polish counterparts. On the other hand, numerous analogies with the loess profiles of the Lower Danube Basin could be demonstrated. In between the upper Pleistocene loess packs, steppe and wooded-steppe soils are fairly frequent. Besides these, there occur particularly in the upper parts of the profiles repeated horizons of slight humus accumulations.

a) Skeletal soils, zones of slight humus accumulation, and humified loess. Their thickness varies between a few tens of centimetres and a metre. The soil is often of the humic-carbonatic type. Animal burrows occur in the overlying and underlying loess as well as in the humified horizon. As to the interpretation of these soils it has to be borne in mind that, rather than representing exclusively autochthonous deposits, they include some deluvial soil sediments as well, a fact occasionally proven by the thickness and stratification of the deposit.

Hydromorphic accumulations of humus and swamp soils have also been recorded.

b) Of the steppe and wooded-steppe soils, several horizons of chernosem-type soils occur in an upper and a lower zone in most of the tall profiles of dry-land loess in the central part of the basin (Figs. 4—6). In the southern part of the Great Hungarian Plains, as well as in the Jugoslavian Vojvodina, chernosem is locally substituted by a pale brown steppe soil (kastannosem). Both types of soil are lime-bearing and contain animal burrows characteristic of steppe soils. Vertical wasp holes of 1 to 2 metres depth extending downward to the soil horizon are also very frequent. The intensely humic chernosem-brown forest soils may in general be regarded as the wooded-steppe facies of the above types.

The climatic conditions of the formation of these chernosem soils must have been those of a dry continental steppe type with no permanent ground frost. This is indicated by the burrows and wasp holes. The presence of the kastannosem in the southern part of the basin presumably indicates an even drier climate. The chernosem soils originally occurring at the deeper levels of the profiles were deluvially reworked and redeposited in several younger layers as chernosem-type slopewash soils (semipedolites).

c) The well-developed B horizons of fossil forest soil occurring in the loess profiles of the Central Danube Basin are mostly of the brown forest soil type, but the "Parabraunerde" richer in clay is also represented. These latter soil horizons generally indicate the lower limit of the upper Pleistocene loess pack, the level of the last interglacial period. This hypothesis is borne

out — besides the palaeopedologic facts — also by the morphologic and stratigraphic position of the loess profiles as well as by the Vertebrate remains found in the loess packs. In some profiles the well-developed forest soil of the last interglacial phase forms a single soil complex with a directly overlying chernosem (Fig. 4).

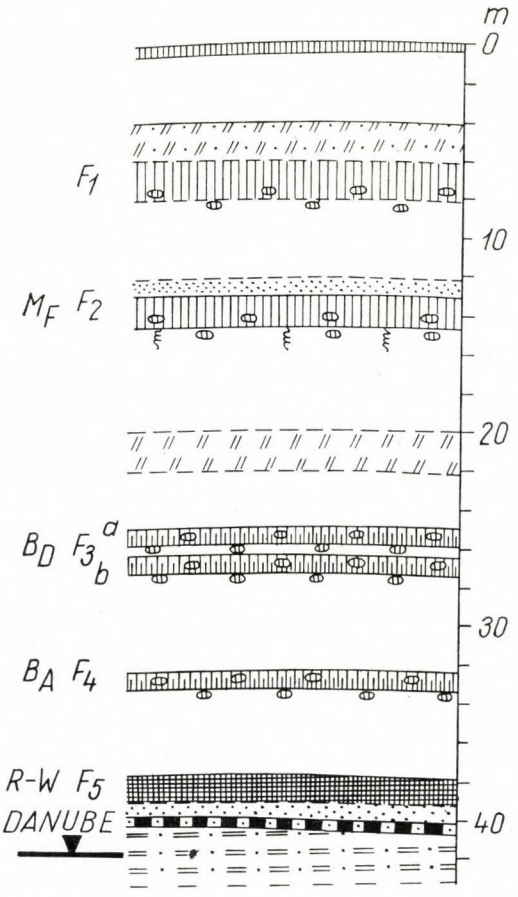


Fig. 6. Loess profile of Erdut (Erdőd) in Jugoslavia

Besides brown forest soils, red clayey soils and reddish adobe soils also occur in the lower level of the loess profiles. In the southern part of the basin as well as on the piedmont slopes of southern exposure these are mostly seen to replace the above-mentioned brown forest soil, either in the soil horizon of the last interglacial phase or below (M—R?) (Figs. 6, 7). The red clayey soils — formed in certain phases of the interglacials — can be attributed to an intense Mediterranean climatic influence. This is indicated by the kaolinite

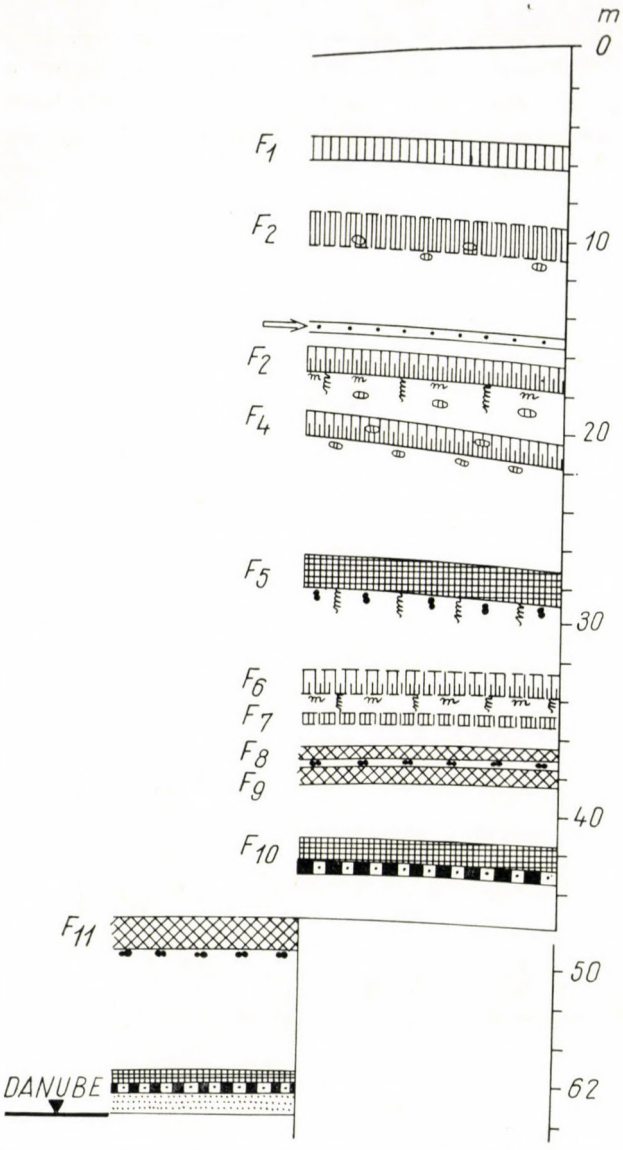


Fig. 7. Sketch profile of the loess wall of Starì Slankamen (Čot) in Jugoslavia

present in the soils and by the intense enrichment of lime in the lower part of the soil profile, in some cases to such a degree that a thin bank of limestone was formed (Figs. 2, 7).

d) The wet-surface soils occur among the loess-like clayey, sandy strata of the upper Pleistocene of fluvial deposition and in the deepest-lying parts of the Great Hungarian Plains (Fig. 8). At the bottom of the profiles of a

total depth of 6 to 8 metres jet-black swampy meadow soils have been disclosed, overlain at a somewhat higher horizon by one or two layers of silty meadow soil. The deciphering of the climate as indicated by these soils is complicated by their intrazonal character and by their occurrence on wet surfaces. However, their presence draws attention to frequent interruptions of deposition that resulted in the revival of soil formation.

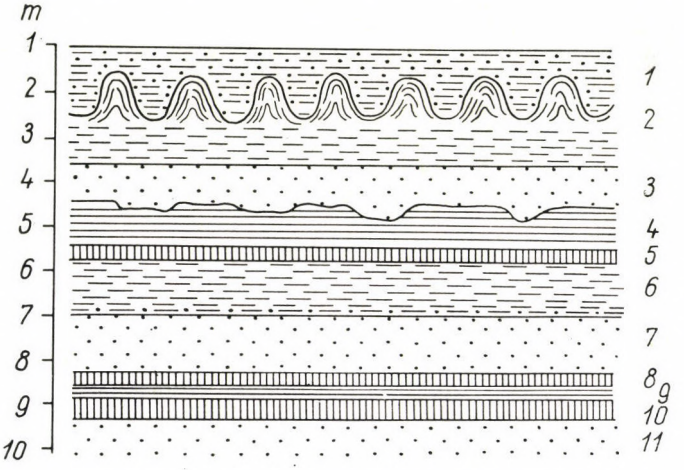


Fig. 8. Detail of the wall No. I of the brickyard of Békéscsaba. 1—5 — fluvial sand sandy clay and loessy silt; 5 — meadow clay soil; 6 — loessy silt; 7 — fine sand; 8 — swampy clayey soil; 9 — dark blue clay; 10 — jet-black swampy meadow clay soil

These pedogenic periods were, however, rather brief. This statement is confirmed by the repeated occurrence of silty meadow soils and meadow soils at large in the silt deposits of the Recent floodplains.

6. Sand layers in upper Pleistocene loess

The stratification of the sand packs and sandy intercalations between the loess packs, the grain size distribution and sphericity of the sand grains exhibit a considerable diversity, which is indicative of a variety of processes of deposition and varying climatic conditions. By using microstratigraphic and granulometric methods it is relatively easy in some cases to distinguish between the fluvial and wind-borne sands and the sands of parallel stratification deposited by the slopewash.

However, the definite classification of these types of deposit is in the majority of cases hindered by the fact that the sandy intercalations had undergone repeated redeposition in the course of their history. Also, the

depositional features of the sand are seen to be effaced partly or entirely by syngenetic or epigenetic processes of alteration. The granulometric approach is also in this case helped by microstratigraphic studies which can shed some light on the origin of the deposits. The sand and silt intercalations between the loess packs of the hummocks and the foothills of the mountains have thus been found to be mostly due to the slopewashing activity of meltwater and precipitation, fluvial and proluvial processes being rather subordinate. On the other hand, the sands intercalated vertically and horizontally between the loessy deposits overlying the extended alluvial fans of the rivers (the plateaux of the Nyírség, the area between Danube and Tisza, Inner Somogy County) have mostly been deposited by the wind, but the fluvial mode of deposition is also encountered.

In the areas where the sand is overlain by loess, the transition between the two kinds of deposit is generally rather gradual. The sand is overlain by a thin layer of loessy sand, sandy loess grading into loess without any noticeable break in lithology. This phenomenon is independent of the nature of the underlying sand, be it aeolian, fluvial, Pleistocene, Pliocene or Pannonian. On a large scale this phenomenon is closely connected with Recent — superficial — and fossil soils, beneath which this sequence is observed in the majority of cases. It is in agreement with several authors that we attribute this phenomenon to a process of loessification and pedogenesis (Berg 1947, Gerassimov 1961, Kádár 1961, Sokolovsky 1961).

In the upper Pleistocene loess profiles of the hills, the fluvial sands are subordinate. Their occasional presence has been attributed to phases of erosion (Ádám—Marosi—Szilárd 1954, 1959, Kriván 1955).

According to our observations the intercalations of sand and loessy sand most often occur in dell fillings and deluvial (occasionally proluvial) slope deposits.

7. Periglacial phenomena of solifluction and cryoturbation; desiccation cracks

In the mountains and hills of the Carpathian Basin the most frequent periglacial ground frost phenomenon apparent in the loess profiles is the reworking of loess or loess-like formations by solifluction, featuring more or less intensely cryoturbated structures, irregular folding of the beds, chaotic mixing of the deposits and banded furrows (Streifenböden) parallel to the slope of the relief.

Most intense solifluctional activity took place in several successive phases in the early Würm, after the evolution of the last-interglacial soil complex in the so-called anaglacial, humid, cool climatic phases, whereas a second series of solifluction phenomena of some importance can be attributed to the climatic fluctuations of the late Würm.

Polygonal wedges penetrating the fossil soils and filled with loess or loess-like material are rather restricted in extension, and occur here and there in the loessy loam of the basin margin (Fig. 9). In the interior of the basin, in the hummocky areas, the moisture content of the loesses was insufficient in the first place to lead to the formation of frost wedges.

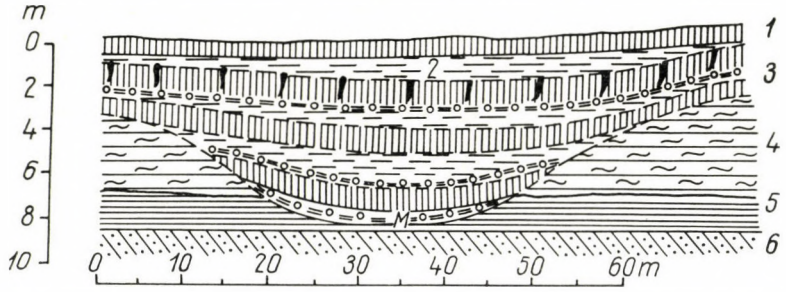


Fig. 9. Detail of the wall of the brickyard of Szombathely. A derasional valley (dell) filled in several rhythms by solifluctionally transported loess. Under the upper fossil soil there is a polygonal pattern, 1.5 m deep, of frost cracks

Also the cryoturbational and solifluctional phenomena observed in certain horizons of the loess profiles offer some important clues as to the conditions prevailing at that time, a fact that has been expounded in more detail elsewhere (PÉCSI 1963, 1964).

8. Other factors affecting the classification of the upper Pleistocene deposits

a) In several upper Pleistocene loess profiles of this country, thin layers of andesite tuffite have been observed (KRIVÁN—RÓZSAVÖLGYI 1964). This persistent layer occurs in the lower third of the upper Pleistocene series (Fig. 2).

b) In several loess profiles an apparently persistent bed of coalified (charred?) fragments of wood is observed (Fig. 4).

c) In the southern part of the basin, particularly in the younger, upper sections of the tall loess bluffs along the Danube in Jugoslavia, there is a pronounced uncorformity locally accompanied by a considerable hiatus (Fig. 7). This younger period of denudation had preceded the formation of the two upper well-developed steppe soil horizons. The denudation is mostly indicated by rolled loess dolls mixed with pebbles of local origin and bedded in a sand not more than a couple of tens of centimetres thick. This phase of denudation also left its imprint on the loess profiles in the interior of the basin. The denudation, as revealed by its mean stratigraphic position, must have been fairly widespread, accompanied locally by the scooping out of dells and arroyos (Fig. 4).

A more ancient and more important phase of denudation was that preceding the formation of the soils of the last interglacial. Its traces are readily observed in the loess profiles of the basin margins and of the Transdanubian hummocks. The phase must have been one of considerable duration, continuing even after the development of the interglacial soils, as these latter were also reworked locally. It was in this period that the majority of the ancient loesses was eroded and that the rivers incised themselves in the second terrace above the floodplain of their mountainous sections. (Late Riss glacial phase and part of the R—W interglacial phase.)

REFERENCES

ÁDÁM, L.—MAROSI, S.—SZILÁRD, J.: Földrajzi Közlemények **2,** (78), 239—254, 1954. — ÁDÁM, L.—MAROSI, S.—SZILÁRD, J.: A Mezőföld természeti földrajza. (Abstracts: Die Geomorphologie des Mezőföld, Fizhicheskaya geografiya Mezefelda.) Földrajzi Monográfiák II, Akadémiai Kiadó, Budapest, 1959. — BORSY, Z.: A Nyírség természeti földrajza. (Physical geography of the Nyírség region.) Földrajzi Monográfiák V, Akadémiai Kiadó, Budapest, 1961. — BERG, L. S.: Klimaty zhizn. Moscow 1947. — BULLA, B.: Földtani Közlöny. **67,** 196—215, and 289—309, **68,** 33—58, 1937 and 1938. — BULLA, B.: Földrajzi Közlemények **67,** 268—281, 1939. — BULLA, B.: Quelques problèmes géomorphologiques interglaciaires de la zone périglaciaire du Pléistocène. Studies in Hungarian Geographical Sciences. Akadémiai Kiadó, Budapest, 1960. — FINK, J.: Mitteilungen d. Geol. Gesellsch. Wien **53,** 249—266, 1960. — FINK, J.: Mitteilungen der Geol. Gesellsch. Wien **54,** 1—25, 1961. — FÖLDVÁRI, A.: Földtani Közlöny **86,** 351—356, 1956. — FRANYÓ, F.: Magyar Állami Földtani Intézet Évi Jelentése 1961-ről, 31—46, 1961. — GERASIMOV, I. P.: Petermanns Geogr. Mitt. **105,** 234—248, 1960. — GERASIMOV, I. P.: Lessoobrazovaniye i pochvoobrazovaniye. (Loess and soil formation.) INQUA VI. Congress. Abstracts of Papers. Lodž 1961. — GÜNTHER, W.: Sedimentpetrographische Untersuchung von Lössen. Köln 1961. — HAASE, G.: Geographische Berichte. **8,** 97—129, 1963. — HORVÁTH, A.: Állattani Közl. **44,** 171—184, 1954. — INKEY, B.: Földtani Közlöny. **8,** 15—26, 1878. — KÁDÁR, L.: Közlemények a KLTE Földrajzi Intézetéből. Debrecen, **19,** 1954. — KÁDÁR, L.: Földrajzi Közlemények **4,** (80), 143 — 163, 1956. — KÁDÁR, L.: Features of the loess plains in the regions of alluvial fans. INQUA VI. Congress. Abstracts of Papers. Lodž 1961. — KEREKES, J.: Beszámoló a Földtani Intézet Vitaüléseinek munkálatairól, 97—149, 1941. — KRETZOI, M.: Acta Geologica **2,** 67—79, 1963. — KRIVÁN, P.: Magyar Állami Földtani Intézet Évkönyve. **43,** 364—512, 1955. — KRIVÁN, P.—RÓZSAVÖLGYI, J.: Földtani Közlöny **92,** 330—333, 1962. — KRIVÁN, P.—RÓZSAVÖLGYI, J.: Földtani Közlöny **94,** 257—268, 1964. — KUKLA, J.: Vestnik Ustr. Ustavu Geologického **36,** 369—372, 1961. — KUKLA, J.—LOŽEK, V.—ZABURA, A.: Quartärband **13,** 1—29, 1961. — LÓCZY, L.: A Balaton környékének geológiája és morfológiája. I. rész. A Balaton környékének geológiai képződményei és ezeknek vidékek szerinti telepedése. I. szakasz. (Geology and relief of the Lake Balaton region. Part I. Geological formations of the region Lake Balaton and their areal distribution. Section I.) A Balaton Tud. Tanulm. Eredményei 1913. — LOŽEK, V.: Quartärmollusken der Tschechoslowakei. Prague, 1964. — MARKOVIĆ—MARJANOVIĆ, E.: Less v Jugoslavii. (Loess in Jugoslavia.) INQUA VI. Congress. Abstracts of Papers. Lodž, 158—159, 1961. — MIHÁLTZ, I.: Magyar Állami Földtani Intézet Évi Jelentése 1950-ről, 113—138, 1953. — MIHÁLTZ, I.: Acta Geologica **2,** 109—121, 1953. — MIHÁLYI—LÁNYI, I.: Alföldi Kongreszszus. Az Alföld földtani felépítése. Akadémiai Kiadó, Budapest, 1953. — MOLDVAY, L.: Acta Univ. Szegediensis, Ser. Min.-Petr. **14,** 75—109, 1961. — MOLNÁR, B.: Földtani Közlöny **91,** 300—315, 1961. — MOSKVITIN, A. I.: Byuleten Kom. po izucheniyu chetvertichnogo perioda **28,** 33—55, 1963. — PEJA, GY.: Borsodi Földrajzi Évkönyv **2,** 5—23,1959. —PÉCSI M.: Inst. Geol. Prace **34,** 187—311, 1961. — PÉCSI, M.: Földrajzi Értesítő **11,** 19—35, 1962. — PÉCSI, M.: Petermanns Geographische Mitt. **107,** 161—182, 1963. — PÉCSI, M.: Biuletyn peryglacjalny. **14,** 279—293, 1964. — PÉCSI, M.: Ten years of physico-geographic research in Hungary. Studies in Geography. Akadémiai Kiadó, Budapest, 1964. — PINCZÉS, Z.: Földrajzi Értesítő **3,** 575—584, 1954. — RÓNAI, A.: Die Bedeutung der Quartärforschung in Ungarn. Institut Geologiczny Prace, INQUA VI. Congress. Lodž, 241—245, 1961. — SCHERF, E.: Versuch einer Eintei-

lung des Ungarischen Pleistozäns auf moderner polyglazialistischer Grundlage. Verhandl. d. III. Internat. Quart. Konf. Wien, 1938. — Sokolovsky, I. L.: Regionalniye i geneticheskiye tipy lessovych porod. (Regional and genetic types of loess formations.) INQUA VI. Congress. Abstracts of Papers. Lodž, 164—165, 1961. — Remy, H.: Eiszeitalter und Gegenwart **11,** 107—120, 1960. — Stefanovits, P.—Rózsavölgyi, J.: Agrokémia és talajtan **11,** 143—160, 1962. — Stefanovits, P.: Magyarország talajai. (The soils of Hungary.) Akadémiai Kiadó, Budapest, 1963. — Sümeghy, J.: Magyar Állami Földtani Intézet Évi Jelentése 1953-ról, 394—404, 1955. — Szádeczky-Kardoss, E.: Földtani Közlöny **66,** 213—228, 1936. — Székely, A.: Földrajzi Közlemények **12,** (87), 199—218, 1964. — Treitz, P.: Földrajzi Közlemények, 225—277, 1913. — Ungár, T.: Hidrológiai Közlöny **44,** 537—545, 1964.

ГЕНЕТИЧЕСКАЯ КЛАССИФИКАЦИЯ ОСАДКОВ В ОБНАЖЕНИЯХ ПЛЕЙСТОЦЕНОВЫХ ЛЕССОВ ВЕНГРИИ

М. ПЕЧИ

Резюме

Наши наблюдения по отдельным лессовым пачкам и погребенным почвам зарегистрированы на многочисленных профилах. Они указывают на то, что формирование отдельных слоев лессовых обнажений Карпатского бассейна не охватило весь промежуток времени стадиала, как это было предположено раньше. Формирование отдельных ископаемых почвенных горизонтов или даже комплексов не должно обязательно быть отождествляемым с полным промежутком времени интергляциала или интерстадиала. За упомянутые промежутки времени обычно произошло накопление ряда слоев. За первичные эоловые отложения нами принимается только часть лессовых пачек, встречающихся в обнажениях верхнеплейстоценовых лессов, это вообще лессы типа «плато». В холмистых и горных областях преобладают главным образом пачки делювиальных — наслоенных — осыпных лессов, в то время как на невысоких конусах выносов — в пределах бывших пойм — господствовало речное осадконакопление.

В лессовых обнажениях Карпатского бассейна можно доказать полигенетическое накопление меняющихся по вертикали пачек осадков. Коренные эоловые накопления не являются так преобладающими, как это предполагалось раньше, ведь вместе с ними часто встречаются также и пачки делювиального, пролювиального, речного и элювиального происхождений. Подробное генетическое подразделение дается в таблице 4.

THE WIND-BLOWN SAND REGIONS OF HUNGARY

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Wind-blown sand covers as much as 25 percent of the area of Hungary. The most extensive wind-borne sand region occurs in the Nyírség, the area between the Danube and the Tisza and in Inner Somogy County. Most of the wind-borne sands overlie Pleistocene alluvial fans.

Among the relief forms the wind furrows, hummocks and dunes and the residual ridges play the most important roles in the area. Parabolic dunes are also fairly abundant between the Danube and the Tisza and in the Nyírség. Most of the parabolic dunes are asymmetric. Further characteristic elements of the alluvial fans are flat surfaces modeled by deflation. The sand blown out of these flats was deposited over fairly large areas sometimes having a parabolic shape. These large heaps mark greater units of rhythm of erosion by the wind.

In the wind-borne sand hummocks, the dominant fraction is fine sand of 0.2 to 0.1 mm diameter. Grain shape studies have revealed the sand of the dunes to have travelled over a fairly short distance.

I.

Almost 25 percent of the area of Hungary is covered by wind-blown sand deposits. The largest sand-covered area in the Great Plains is that between the Danube and the Tisza as well as in the Nyírség region and in Inner Somogy County. Further areas of sand-dune relief may be encountered in the Mezőföld, the Little Plains, in the NW foreland of the Vértes Mountains, in the Tápióság, on the alluvial fans of the Zagyva and Tarna rivers, along the Tisza river, the area between the Tisza and the Kőrös rivers, the area between the Bodrog and Tisza, in the Taktaköz region and along the Ipoly river (Fig. 1).

In the early beginning of this century, J. CHOLNOKY obtained valuable results from the study of the relief forms developed by the wind-blown sand and their systematization. In the thirties, the study of the wind-blown sand areas gained new impetus through the activity of L. KÁDÁR. Concurrently the geological studies of J. SÜMEGHY on the history of evolution of the wind-blown sand areas east of the Tisza river also furnished some important information concerning the topic under discussion.

Since 1950 the wind-blown sand areas are being extensively studied in detail (KÁDÁR, BULLA, SÜMEGHY, GÓCZÁN, MAROSI, PÉCSI, SZILÁRD, BORSY, ERDÉLYI, URBANCSEK, FRANYÓ).

II.

Most of the wind-blown sand in Hungary occurs on alluvial-fan surfaces of Pleistocene age. The volume of the wind-blown sand on the Holocene and late Pleistocene terraces along the Danube and the Ipoly rivers is insignificant as compared to the former.

In the beginning the forms described from the wind-blown sand areas included wind furrows, hummocks, residual ridges and waterside dunes. It was KÁDÁR who drew attention to the presence of parabolic dunes.

Comparative morphological research on the diverse wind-blown sand areas has lately revealed that the forms characteristic of the wind-furrowed relief type are dominant everywhere except for the Nyírség. However, the aspect of two wind-furrowed areas may be substantially different even over one and the same alluvial fan. The reason for this is the variations in the wind system at different points of the alluvial fans of large size. Furthermore, the depth of the ground water table and the density of the vegetation may also exhibit considerable differences. The composition of the sand is not necessarily uniform, either. A rich diversity of wind-furrowed relief types is encountered particularly in the Nyírség and in the area between the Danube and the Tisza (Figs. 2, 3), but Inner Somogy County also exhibits a fair degree of variety.

The shape and size of the *wind furrows* varies within broad limits. In Inner Somogy County, in the Mezőföld, in the area southeast of Budapest and in the southern part of the region between the Danube and the Tisza, as well as in the northeastern corner of the Nyírség, many furrows are 1 to 2 kilometres long. The breadth of the prolonged furrows is 50 to 250 metres, exceptionally even 400 metres (Nyírség, region between the Danube and the Tisza). The majority of the furrows is, however, less than 750 metres long. These are either oblong, oval, or circular in shape. In the wind-blown sand areas the shallow furrows (not deeper than 5 metres) are encountered more often. Deeper ones mostly occur in the northern part of the Nyírség and in the parts of greater relief energy of the region between the Danube and the Tisza.

The furrows occasionally constitute long chains (Fig. 2). In this case the individual furrows are separated by low divides. The sand blown out of the furrows is heaped up at the end of the furrow chain either in the form of a string of hummocks or as thinly spread layers. There also occur examples of the material blown out of the furrows being deposited considerably farther away.

The sand blown out of the furrows mostly constitutes *sand hummocks* (hummock dunes). In the Hungarian wind-blown sand areas three types of such form are observed, those of parabolic, oblong and irregular outlines respectively.

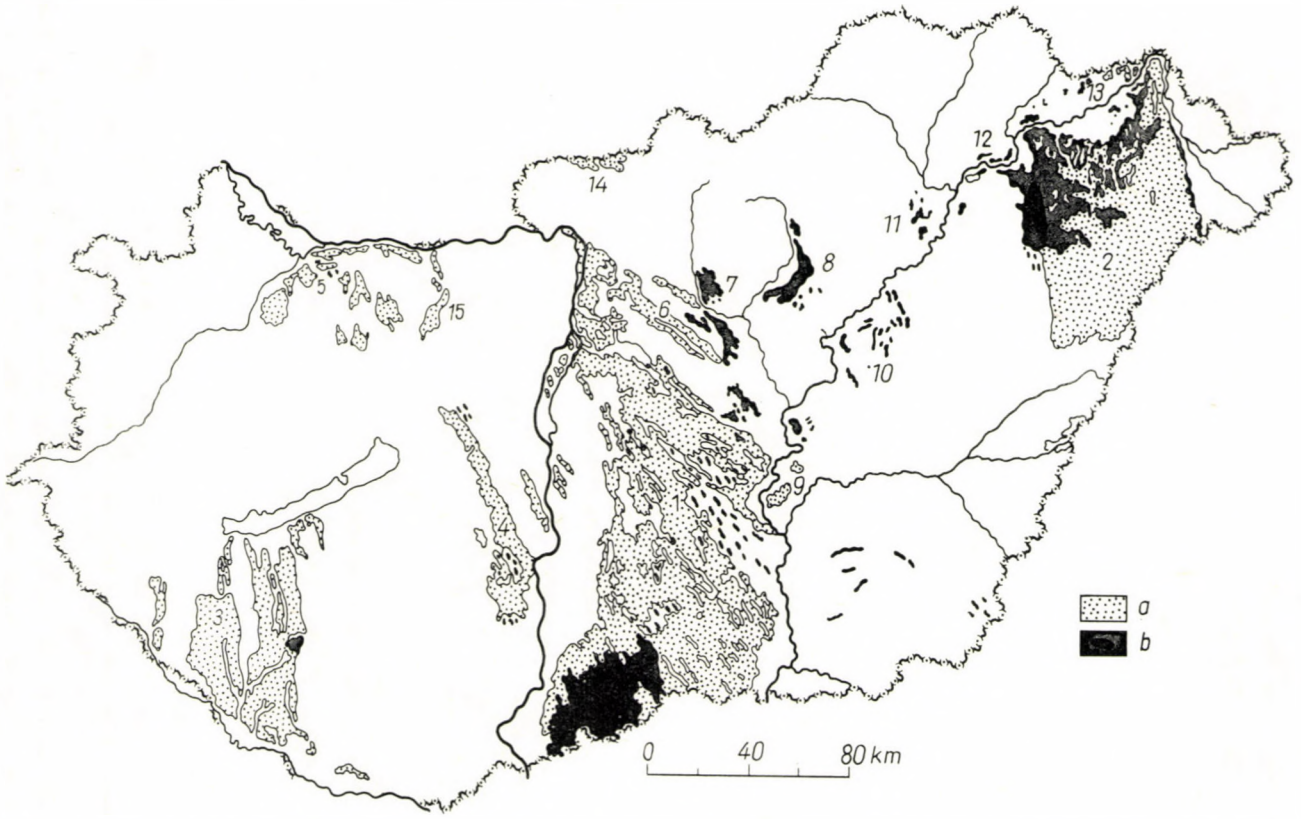

Fig. 1. The extent of wind-blown sand in Hungary; *a* areas of wind-blown sand; *b* sand hummocks overlain by loessy sand, sandy loess or loess; 1. Wind-blown sands between the Danube and the Tisza; 2. Nyírség; 3. Inner Somogy; 4. Mezőföld; 5. Wind-blown sand in the Little Plain; 6. Sand area of Tápióság; 7. Sand dunes along the Zagyva river; 8. Sand dunes along the Tarna river; 9. Tiszazug; 10. Sand dunes of the Nagykunság; 11. Sand dunes of the alluvial fan of the Sajó river; 12. Taktaköz area; 13. Area between the Bodrog and the Tisza (Bodrogköz); 14. Sand area along the Ipoly river;15. Sand dunes in the northwestern foreland of the Vértes Mountains

The parabolic hummocks are mostly situated where the sand blown out of the furrows was immediately arrested by the plant cover. This type is very common, its finest examples are noticed in the northeastern part of the Nyírség, and in the area between the Danube and the Tisza (Ágasegyháza, Izsák, Bugac, Orgovány).

The longitudinal dunes are much more frequent and are regularly present all over the wind-blown sand regions of this country. The length generally

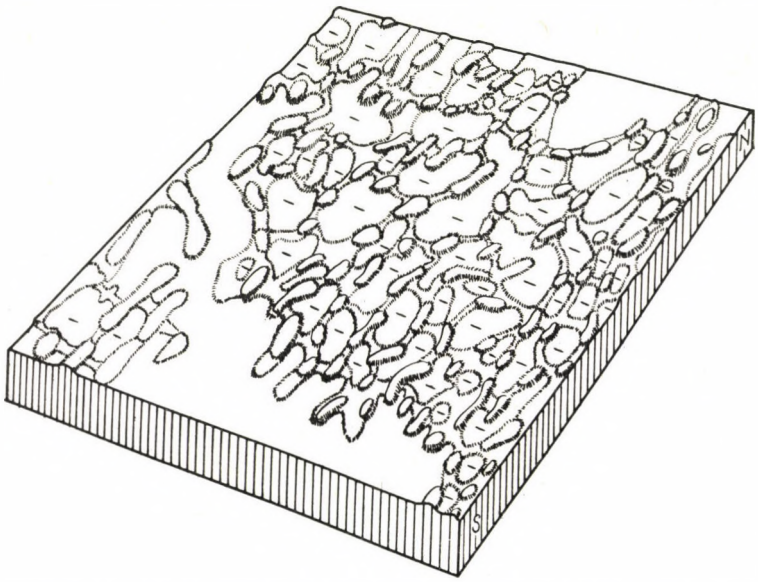

Fig. 2. Wind-furrowed surface from the centre of the Nyírség

varies between 100 and 400 metres. The outline is oval, the top slopes more gently towards the north than towards the south. The altitude of these dunes is different in every region. In areas of high relief energy they may be higher than 10 metres, but in the majority of cases it is lower than 6 metres. Longitudinal dunes are developed where the sand surface was less intensely covered by a sparser plant cover. The longitudinal dunes frequently constitute strings consisting of 3 to 6 dunes. The links between the members of the string elements may be more or less close. Often the dunes of the string are quite close together, and in this case the form resembles a long-drawn residual ridge.

In Inner Somogy County, in the Mezőföld, the Nyírség and in the area between the Danube and the Tisza there occur sand ridges more than one kilometre long that are connected with wind-blown furrows. These ridges constitute a particular type of longitudinal dunes.

In the Hungarian wind-blown sand areas whose relief presents a variety of aspects, the wind furrows are occasionally linked with hummocks of completely irregular outlines. The hummocks may even be absent.

On the wind-furrowed surfaces *residual ridges* are fairly frequent. The ridges elongated in the direction of the dominant wind are 2 to 15 metres tall. The trace of the ridge may be straight or bent, with a length varying between 150 to 800 metres. Such long ridges (maximum length, three kilo-

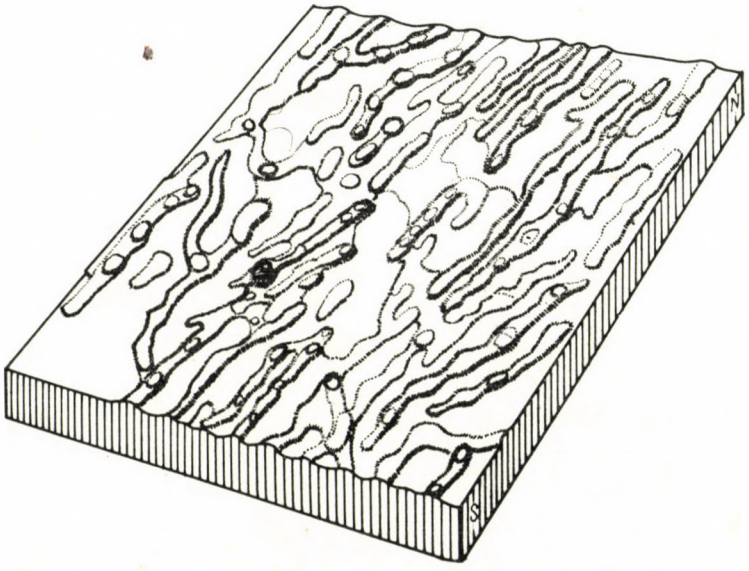

Fig. 3. Wind-furrowed surface from the NW part of the Nyírség

metres) occur in the south-western part of the region between the Danube and the Tisza. In the Nyírség and in Inner Somogy County, residual ridges 1 to 1.5 kilometres long have also been observed.

Interspersed with the wind-blown sand areas of the Nyírség and the area between the Danube and the Tisza there exist *entirely flat surfaces of fairly great extent.* It was found that there is a close connexion between these latter and the wind-blown sand areas to the south or south-east. The sand of the wind-blown sand surfaces was mostly derived from these flat areas, the latter *being sculptured by deflation* during the intense phases of wind activity.

The sand blown out of the broad flats is in the majority of cases deposited in the form of extensive *sand covers.* The diameter of these latter may exceed 10 kilometres and they may include hundreds of smaller forms such as wind furrows, hummocks, residual ridges, etc.

In the Nyírség, between the Danube and the Tisza and in Inner Somogy County there also occur sand covers of a parabolic outline. The diameter of these latter varies from 5 to 8 kilometres. When inspected from an elevated point of vantage, these parabolic forms of the Nyírség look remarkably homogeneous and only a closer scrutiny reveals the inhomogeneity of the surface.

In the southern part of the Nyírség the *parabolic dunes* are dominant. Though frequent in the area between the Danube and the Tisza, they are of

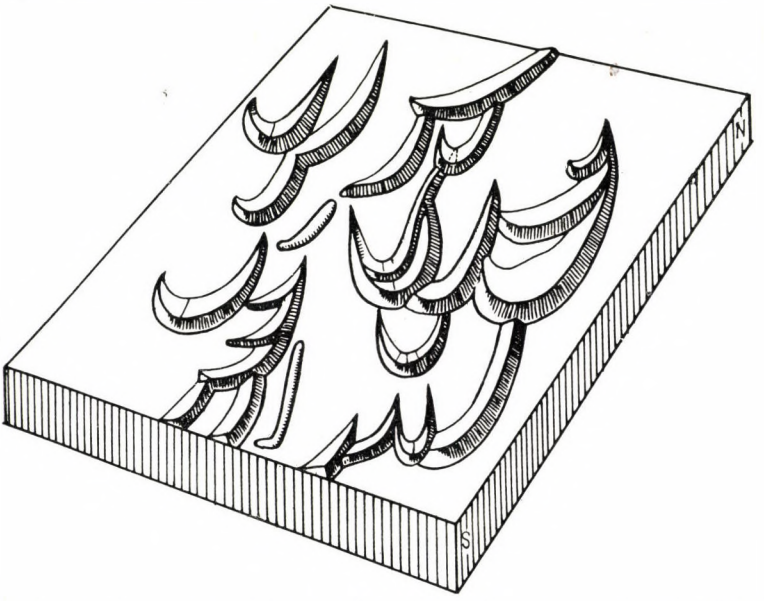

Fig. 4. Parabolic dunes and parabolas with rudimentary west wing (Nyírség)

a rather subordinate importance among the relief forms. A few also occur on the alluvial fan of the Tarna and in the Tápióság, but in Inner Somogy County, in the Mezőföld, on the alluvial fan of the Zagyva and in the Kisalföld not a single one has been recorded.

The majority of the parabolic dunes in Hungary are asymmetric. In the southern part of the Nyírség the dominant form of parabolic dune exhibits a rudimentary western wing (Fig. 4). On the other hand, in the area between the Danube and the Tisza, the symmetric form is more abundant. Asymmetric parabolic dunes in this latter region belong to two groups. In the dunes of one group the western wing is shorter and these resemble the Nyírség type. In the other group it is the eastern wing that is less well developed. This group has not been encountered in the Nyírség.

Between Soltvadkert and Izsák and in the Tápióság there are crescent-shaped, almost completely straightened parabolic dunes.

In the Nyírség area some of the parabolic dunes in the course of their advance approached close to a water-logged area. In this case their eastern wing was bogged down. As a result, the dune gradually developed into a long hummock ending in a small parabola. This form has been described by L. KÁDÁR under the name of rand dunes (Fig. 5).

The finest examples of parabolic dunes are observed in the Nyírség area. The eastern wing often attains the length of 1.5 km. The paraboles between

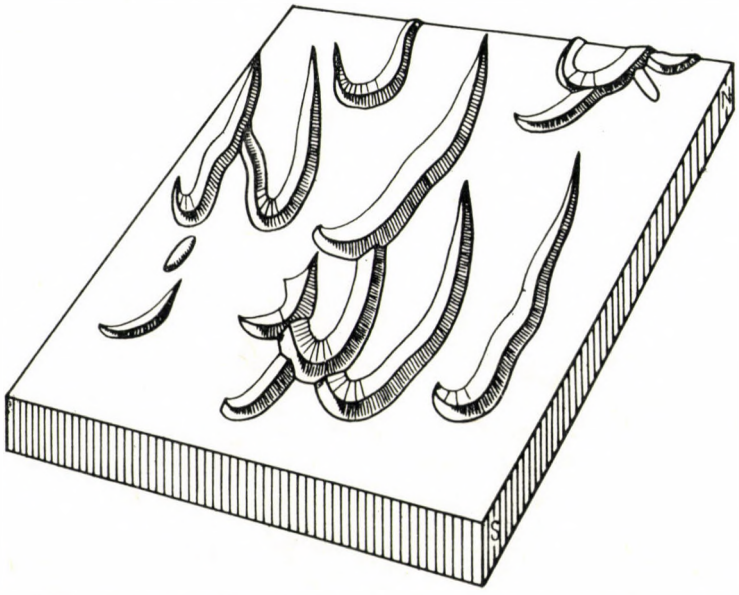

Fig. 5. Rand dunes and parabolas of rudimentary west wing (Nyírség)

the Danube and the Tisza are substantially smaller than those of the Nyírség. Their wings do not as a rule exceed 500 metres.

The height of the peak of the Hungarian parabolic dunes ranges from 2 to 18 metres.

From the areas adjacent to the Tisza river CHOLNOKY also described waterside dune types (Nagykunság, Taktaköz etc.). In his opinion the sands of these dunes were blown by the northwesterly winds out of the Tisza bed in times of low water.

Subsequent research has failed to confirm the views of CHOLNOKY. Also in these areas the forms characteristic of the wind-furrowed surfaces are dominant.

The strike of the forms treated so far is NW—SE, NNW—SSE or N—S in most of the cases. In the Nyírség and between the Bodrog and Tisza rivers forms with N—S, NNE—SSW and NW—SE strikes are observed.

III.

Stratigraphic, pedologic and palynologic evidence concurs to prove that Würm III was the main phase of sand movement in the Hungarian wind-blown sand areas. Exceptions are found in Inner Somogy County and in the Tarna river area, where iron-banded soils prove the movement of sand to have taken place in the middle of the Würm or (in the case of Inner Somogy County) even earlier.

On the alluvial fans the movement of the sand was particularly intense at the time of the cold peak of Würm III. Under the climate of that phase, certainly colder and drier than that of the present, the high-energy winds blew everywhere a great deal of sand out of the alluvial-fan surfaces hardly protected by sparse vegetation. Towards the end of Würm III, when the climate became slightly more humid, sand movement decreased a little. The low-lying hummocks were often fairly covered by loessy sand, sandy loess or even by loess. This cover preserved the late Pleistocene land forms over fairly large areas. The loess or loessy sand, also highly valued from the agricultural point of view, permits one to establish the age of the dunes (besides preserving the forms) and indicates the main wind direction prevalent in the Pleistocene. The study of the Pleistocene hummocks covered with the loessy deposits revealed that there is no essential difference between these latter and the forms developed in the hazel phase. It could be established further that the large flat deflated areas formed on the alluvial fans and those in the adjoining zones of deposition were developed in the course of the Würm, and have not undergone any substantial change since.

The strike of the wind-sculptured forms of the Pleistocene remarkably coincides with those of the hazel phase. This goes to show that in this country there was no significant difference between the wind directions of the late Pleistocene and Holocene, although the intensities might have been slightly different.

In the Holocene, at the time of the dry warm hazel phase (between 8000 and 5000 B. C.) the sand started to move again from those areas where the thickness of the loessy cover was insufficient to protect the earlier forms. New forms were sculptured particularly in the wind-furrowed regions. The earlier forms were destroyed and instead new wind furrows, hummocks and residual ridges came to exist.

Locally the strong winds even destroyed the loess cover and shifted the uncovered loose sand in a south—southeasterly direction to the top of the loess-covered surfaces. Many exposures indicate that the extent of the surface covered by loessy deposits was greater at the end of the Würm than today.

In the hazel phase some areas formerly dominated by fluvial erosion or deposition came under the influence of wind action (the alluvial fan of the Galga river, areas along the Danube in the Great Plains, etc.).

Sand movement was considerably restricted in the humid oak and even more humid beech phase succeeding the hazel phase, but was again increased as a result of the deforesting landscape-forming activities of Man during the 18th and 19th century in particular. This new advance of sand was checked by afforestation, the plantation of forest hedges and rational cultivation. Freely moving loose sand is restricted today to a few spots, most of which occur between the Danube and the Tisza.

IV.

The thickness of the loess or loessy cover overlying the sand dunes varies between a few centimetres and 3.5 metres. Locally (e.g. on the alluvial fan of the Tarna river and between the Danube and the Tisza) there also occur in the dunes layers of sandy loess or loessy sand of 10 to 50 centimetres thickness, revealing that the deposition of the wind-blown sand was not an uninterrupted process.

In the hummocks not covered by loess and where the wind-blown sand constitutes an acid soil, down to a depth of 6 metres we find an accumulation of iron compounds in bands of thicknesses ranging from 2 mm to 40 cm for the most part, and from 1 to 5 cm in some cases. Their formation took place under a forest cover, mostly in the oak and beech phases. In some hummocks there also occur iron bands formed in the early Holocene and even in the Würm(Inner Somogy County, alluvial fan of the Tarna).

In the interior of the wind-blown sand hummocks there occur one or several levels of fossil soil in almost every alluvial fan. In most cases there is only one level formed in the early Holocene or later (probably also in the Würm in Inner Somogy County). In some exposures there are two levels of fossil soil (early and young Holocene).

In the wind-blown sand of Hungary the percentual abundance of fine sand of 0.2 to 0.1 mm grain size is greatest almost everywhere. This is particularly so in the large areas of wind-blown sand. Thus e.g. in the Nyírség the grains under 0.2 mm size constitute almost without exception, more than 70 percent of the deposits, and in the southern parts of the Nyírség this proportion even exceeds 90 percent locally. Similar conditions prevail between the Danube and the Tisza, along the Tısza, in the Taktaköz and the area between the Bodrog and the Tisza. Over the entire region the dominance of the 0.32 to 0.2 mm grain size fraction is very rare indeed. On the other hand, the abundance of the grains removed by washing — that is, under 0.01 mm — may attain 3 percent.

As revealed by grain shape studies most of the grains of the wind-blown sands in Hungary did not travel very far. The best-rolled wind-blown sand occurs in Inner Somogy County. The next best is found in the Nyírség, but

even the Nyírség sand is considerably less worn than that of Inner Somogy. In the largest wind-blown sand area of the country, between the Danube and the Tisza, the sands hardly moved a few kilometres. Of course, the sands of the Nyírség are also of a nearby derivation, but their transport was slightly more pronounced.

In the smaller heaps of wind-blown sand all over the country the rolling of the wind-blown sand is very poor. However, the sands of the smaller rivers (the sources of these sands) were also more angular than those of the larger rivers.

REFERENCES

ÁDÁM, L.—MAROSI, S.—SZILÁRD, J.: A Mezőföld természeti földrajza. (The physiography of the Mezőföld.) Akadémiai Kiadó, Budapest, 1959. — BORSY, Z.: A Nyírség természeti földrajza. (Physiography of the Nyírség.) Akadémiai Kiadó. Budapest, 1961. — BULLA, B.: Földr. Könyv- és térképt. Ért. **10—12,** 101—116, 1951. — CHOLNOKY, J.: Földtani Közlöny **32,** 6—38, 1902. — CHOLNOKY, J.: Földrajzi Közlemények **35,** 381—405, 1907. — CHOLNOKY, J.: Földtani Közlöny **42,** 258—294, 1940. — ERDÉLYI, M.: Földr. Ért. **9,** 257—271, 1960. — FRANYÓ, F.: Magyar Áll. Földtani Int. Évi Jelentése 1961-ről, **2,** 31—44, 1964. — GÓCZÁN, L.: Földrajzi Értesítő **4,** 301—315, 1955. — KÁDÁR, L.: Földrajzi Közl. **63,** 4—15, 1935. — KÁDÁR, L.: Földr. Közl. **67,** 342—348, 1939. — KÁDÁR, L.: Sivatagi erózió. (Desert erosion.) Mimeographed textbook of Debrecen University. 1949. — KÁDÁR, L.: Földr. Könyv- és Térképtár Ért. **10—12,** 117—132, 1951. — KÁDÁR, L.: Földrajzi Közl. **4, (80),** 143—157, 1956. — MAROSI, S.: Földr. Értesítő, **4,** 279—298, 1955. — PÉCSI, M.: A magyarországi Duna-völgy kialakulása és felszínalaktana. (Evolution and relief of the Danube valley in Hungary.) Akadémiai Kiadó, Budapest, 1959. — PÉCSI, M.: Földr. Közl. **9, (85),** 1—22, 1961. — SÜMEGHY J.: A Tiszántúl. (The Trans-Tisza region.) Magyar Tájak földtani leírása. Budapest, 1944. — SÜMEGHY, J.: Földrajzi Könyv- és Térképtár Ért. **10—12,** 75—100, 1951. — SZILÁRD, J.: Földrajzi Ért. **4,** 263—278, 1955. — URBANCSEK, J.: Földrajzi Értesítő **12,** 1—28, 1963.

ОБЛАСТИ РАЗВИТИЯ ЭОЛОВЫХ ПЕСКОВ В ВЕНГРИИ

Э. БОРШИ

Резюме

В Венгрии известны обширные области развития эоловых песков. Они занимают приблизительно 25% от общей площади страны. Особенно широкие площади покрыты ими в междуречье Дуная и Тиссы, в Ньиршеге и в Центральной Шомоди. Эоловые пески Венгрии в основном формировались на плейстоценовых конусах выносов.

Из морфологических форм районов, покрытых эоловыми песками, наиболее значительную роль играют эоловые борозды, дюны различных форм и остаточные хребты. В междуречье Дуная и Тиссы и главным образом в Ньиршеге в значительном количестве представлены также параболические гряды. Большинство параболических гряд имеет несимметричную форму. Для конусов выносов характерны также пологие широкие поверхности дефляционного происхождения. Выдутый из них песок обычно накоплен в виде крупных форм (иногда параболических). Они отражают большой ритм ветровой эрозии.

В грядах эоловых песков преобладают тонкозернистые пески (с диаметром от 0,2 до 0,1 мм).

Судя по результатам изучения окатанности, пески гряд не перемещались много вперед.

PERIGLACIAL DERASION AND QUATERNARY VALLEY SCULPTURE IN HUNGARY

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In the mountainous and hilly areas of Hungary more than two thirds of the surface is occupied by characteristic so-called derasional valleys of basin- or bowl-like cross section, exhibiting no trace at all of a permanent stream or valley-bottom incision. Their detailed study is a relatively recent undertaking. In this country it dates back no farther than 1955.

Investigations into the subject have revealed that these valleys, frequent on hills consisting of loose sedimentary material, are nonetheless present also in the mountains on rocks of a wide variety of hardness as well as on gravel sheets and terrace surfaces. Consequently, their formation is governed in the first place by climatomorphologic factors rather than by lithology.

The majority of the derasional valleys in Hungary are relics of the Pleistocene period of periglacial climate. In the Holocene the natural conditions were unfavourable for derasional valley sculpture, but human activities led to their revival.

In the evolution of the derasional cross section of these valleys the proportion of areal denudation parallel to the slope and of linear erosion acting along the axial line of the valley is the decisive feature. In the case of a derasional valley the proportion is shifted in the favour of the areal processes, a fact proven by the stratification, parallel to the surface of the ancient relief, of the valley filling.

Under periglacial conditions and on clayey surfaces the sculpture of the slopes was due mostly to solifluction, in sandy areas to sheetwash by meltwater and precipitation (pluvionivation). Landslides and slumps also contributed to the broadening of the valleys. The removal of the deposits accumulated in the valleys can be explained by the assumption of periodical linear erosion, whose activity left no permanent trace however.

The classification of the Hungarian derasional valleys is not yet of a general validity being restricted to the characteristic types of certain landscape units. The study of the derasional valleys is brought into the foreground by their considerable importance in relief evolution on the one hand and the spreading interest in detailed geomorphologic mapping on the other.

Oblong depressions of sligth axial slope, bounded by gently dipping flanks having a cross section recalling a basin, a bowl or a halved cylinder, that were considered earlier as corrasional valleys, are among the characteristic landscape forms of the hummocky, hilly and mountainous areas of Hungary. These valleys do not as a rule contain a permanent stream; on the contrary, even incisions due to the waters of occasional showers and to the melting of snow are lacking. Corrasion is understood in a variety of ways in international literature, being considered by some authors as an exogenous process, by others as an almost-synonym of erosion, while most of the geographers of this country have adopted the term derasion for this slow process of areal denudation (from the Latin deradere — to scratch off), coined lately by M. PÉCSI (1965).

We shall also in the following consistently employ this term for the landscape forms whose more or less exact synonyms are the German Delle, the French vallée en berceau and the Russian balka.

Attention was first drawn by SCHMITTHENNER (1925) to this characteristic feature of the terraced landscapes of Germany. B. BULLA (1954, 1962) made repeated mention of deraded valleys in Hungary. In the lack of sufficient evidence, however, BULLA assumed this type of valley to be restricted to hilly areas underlain by clayey deposits. In his opinion the deraded valleys of the clayey surfaces were sculpted in the first place by landslides and — as he was the first to point out — by Ice Age solifluction.

In Hungary a detailed study of the derasional valleys has been initiated in about the mid-fifties (PÉCSI 1955, 1961, 1962, 1964, PEJA 1959, PINCZÉS 1960, SZÉKELY 1961, SZILÁRD 1963, ÁDÁM 1964). As a result of these studies it turned out that these forms, although frequent indeed on the hills of gentler slopes underlain by loose deposits, occur just as well in some parts of moderate relief energy of the Hungarian Mountains, on rocks of any type and hardness (dolomite, limestone, volcanics). According to findings by PÉCSI, they are not infrequent, either, on top of gravel sheets and on terraces mostly consisting of sandy and gravelly deposits. Their evolution is consequently not controlled by lithology, although it is distinctly promoted by loosely compacted deposits covered by sparse vegetation (clay, adobe, sand, varieties of loess, slope deposits) and by a gentle relief, the decisive factor of their genesis having been *climatic-morphologic features*. According to the results arrived at up to the present, it was particularly the conditions of areal denudation under a Pleistocene periglacial climate that furthered the sculpturing of derasional valleys (PÉCSI 1961, SZÉKELY 1961, SZILÁRD 1963).

The majority of the derasional valleys furrowing the hilly and piedmont surfaces of this country are *the relics of the periglacial climate* that prevailed in the Pleistocene. This has been proven by the detailed investigation of a number of outcrops on the flanks and on the floor of this type of valley. The majority of the derasional valleys scooped out in the Pleistocene attained their definite shape in the young periglacial phase.

The changed climatic conditions of the Holocene have severely curtailed the natural opportunities of derasional valley formation. As a result of agriculture, however, particularly in the regions of loose sediments, areal redeposition downslope, that is, the evolution of derasional-type cross sections, was accelerated again, surpassing the rates of earlier times (PATAKI 1961).

The majority of the workers in this country have become convinced that the cross section peculiar to the derasional valleys of the Hungarian area is a result of *the combination in a certain proportion of areal denudation* acting parallel to the valley flank on the one hand and of *linear erosion*, acting along the valley axis, on the other. Whereas the evolution of the so-

called erosional cross section is governed by the linear and lateral erosion of the stream, the derasional valleys are due in the first place to a predominantly areal denudation and accumulation downslope and only in a very small proportion to linear incision and transportation along the valley axis. Lately, research has succeeded in demonstrating the traces of areal processes contributing to the sculpture of the valley flanks: the *valley fillings* stratified parallel to the flanks of the valley, a few metres thick in general but exceptionally attaining a thickness of 20 metres, constitute further evidence as to the derasional mode of evolution of the valley.

In the mountains and piedmont areas of Hungary the processes of *solifluction* played the leading role in the sculpture of derasional valleys (freeze-and-thaw solifluction, congelifraction, PÉCSI, 1964). On these surfaces a great deal of congelifractate detritus was available: after through mixing with clayey soil particles, especially in the humid (ana-, cata-glacial) phases of the period in question, this detritus could move downslope throughout protracted intervals of time, especially in the months of the snowmelt in spring and early summer (TROLL 1944, 1957, BÜDEL 1944, 1960, MENSCHING 1953, WICHE 1958).

In the periglacial period, solifluction was a transporting agent of considerable importance in the hilly regions where clayey deposits were predominant, particularly on the Tertiary Schlier surfaces of the hills and hummocks encircling the Northern Mountains (PEJA 1959, SZÉKELY 1961).

Over deposits containing little clay or none at all, consisting mainly of sand and loess-like deposits, fairly widespread in some areas (the hills of SE Transdanubia), the derasional valleys were scooped out — likewise under a periglacial Pleistocene climate — by sheetwash (meltwater + precipitation = *pluvionivation*, PÉCSI 1964). As a result of these processes the valleys in question were filled to a considerable extent with deposits consisting of a motley mixture of sand, some detritus, occasionally gravel, and diverse loess fractions, derived from the ridges and elevations situated between the valleys. These ingredients occur in layers that may be locally as thin as a few millimetres, persistent nevertheless throughout the valley section, invariably parallel to the slope of the ancient relief, wedging out very seldom. (Fig. 1). The Pleistocene age of these deposits is proven besides the fossil soils occurring as intercalations also by the easily recognized syngenetic cryoturbational forms in the profile (PÉCSI 1961).

On slopes of a somewhat more marked relief and particularly on clay, the broadening of the valleys was partly effected by *landslides* and *slumps*. Derasional valleys considerably broadened by landslides have been described from the northern foreland of the Northern Mountains by PEJA (1959) and from the northerly slopes of the Gerecse Mountains right above the Danube by PÉCSI (1955).

The processes of both solifluction and pluvionivation were repeatedly interrupted for periods of various length by climatic oscillations as well as by local changes in physiographic conditions, as proved in numerous instances by the fossil soil horizons in the valley filling (Fig. 2, 3, 4), (PÉCSI 1961, SZÉKELY 1961, ÁDÁM 1964, SZILÁRD 1963).

The phenomena of solifluction and pluvionivation active in the derasional valleys resulted, particularly under the aforementioned climatic conditions,

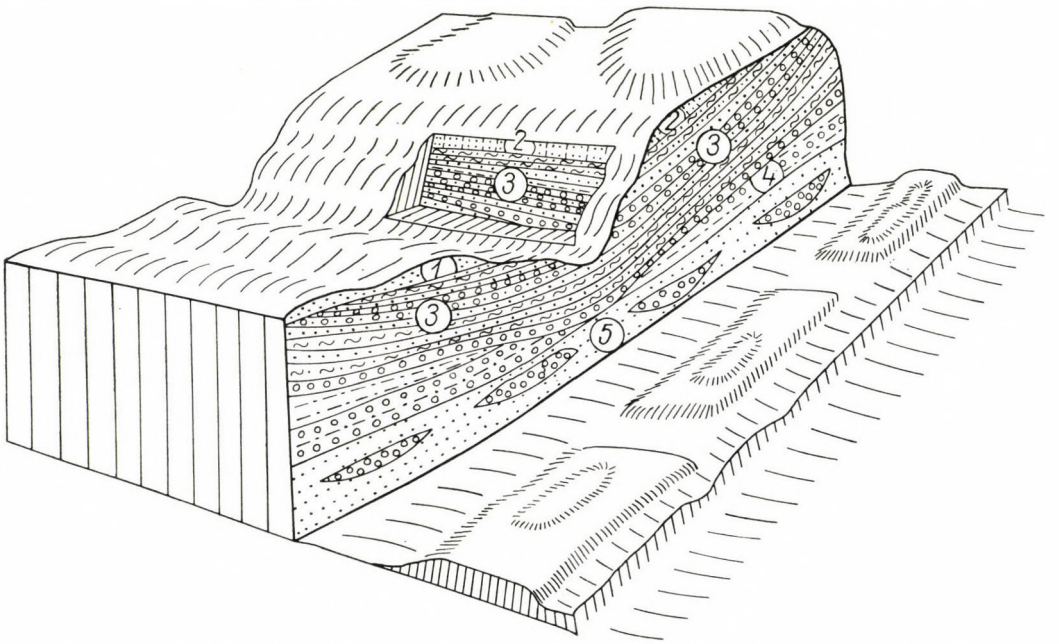

Fig. 1. A late Pleistocene derasional valley filled with a variety of derasional deposits and further deepened in the Holocene, on a slope descending to the southern shore of Lake Balaton. 1 — Loessy sand, 2 — Derasional deposit consisting of sandy loess, strings of gravel, finely stratified, 3 — Late Pleistocene sand bar of Lake Balaton (muddy sand with fine gravel and abundant Gastropod shell fragments), 4 — Lower Pleistocene fluvial deposit (sand with lenticles of gravel), 5 — Wind-borne sand

in a rather sluggish relief evolution. Jointly with the landslides, these phenomena brought about the broadening of the valleys, the reduction of the slope angles and the filling of the valleys with slope deposits. Above the line of inflexion of the slope, on the rim of the valley flanks, and even farther up, on the parts of the ridges and elevations that sloped gently towards the valley, a slow areal denudation of the surface took place, gradually widening the upper slopes of the valleys. Simultaneously the valley was filled up below the line of inflexion. The sediments removed from the former were deposited in the latter; the flat basinlike cross section of the valley was further enhanced by this process.

Several lesser valleys of this type had already been filled up by processes of derasion by the end of the Pleistocene. In the loosely compacted deposits of the hummocky regions of this country, almost every outcrop of some importance exhibits one or several completely filled, buried derasional valleys (Figs. 2, 3).

These processes, although not yet fully understood, offer a satisfactory explanation for the broadening, flattening and filling of the derasional valleys.

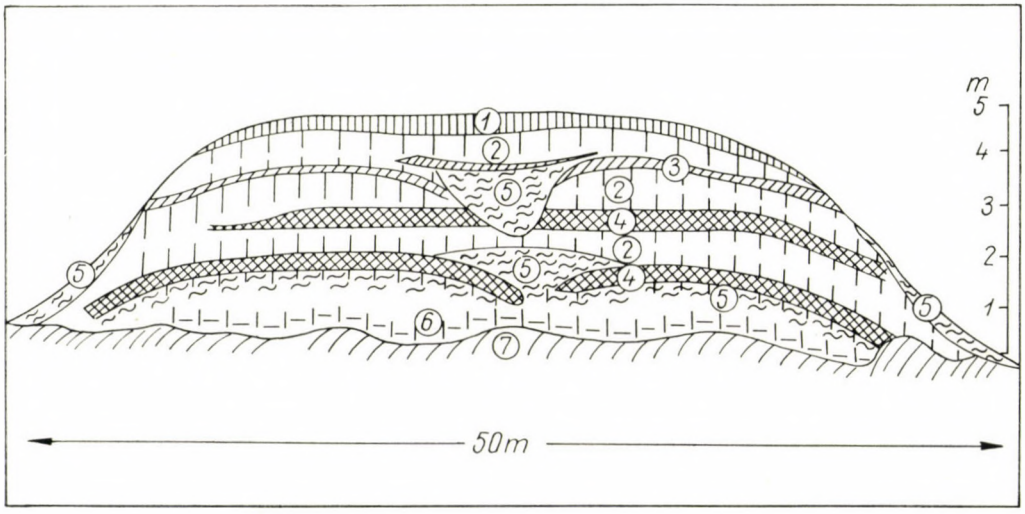

Fig. 2. Filled-up and buried late Pleistocene minor derasional valleys in the hummocky region of Southern Transdanubia. 1 — Chernosem-brown forest soil, 2 — Loess, 3 — Chernosem-type fossil soil, 4 — Reddish-brown fossil adobe zone (B horizon of brown-earth type soil), 5 — Finely stratified sandy-loessy derasional deposit with inclusions of fossil soil, 6 — Loamy loess, 7 — Talus

However the evolution of these latter must necessarily have been initiated by some *linear process* that traced the course of the valley. A further problem is as to how the larger and longer Pleistocene derasional valleys that are still conspicuous features of the landscape to-day could persist up to the present. In the opinion of several workers the initial incision of these valleys took place by linear erosion in one of the humid phases of the Pleistocene (Marosi 1962, Ádám 1964, Szilárd 1963). Forms of smaller size could be initiated by landslides (Peja 1959, Székely 1961, Pécsi 1961). The persistence of the larger derasional valleys since the Pleistocene cannot be conceived except under the assumption that the derasional deposits had been removed time and again from the valley. The filling of the valleys having an extended drainage area could be removed by periodical showers and meltwater in the erosional mode. The traces of these processes cannot be recognized any more in the present

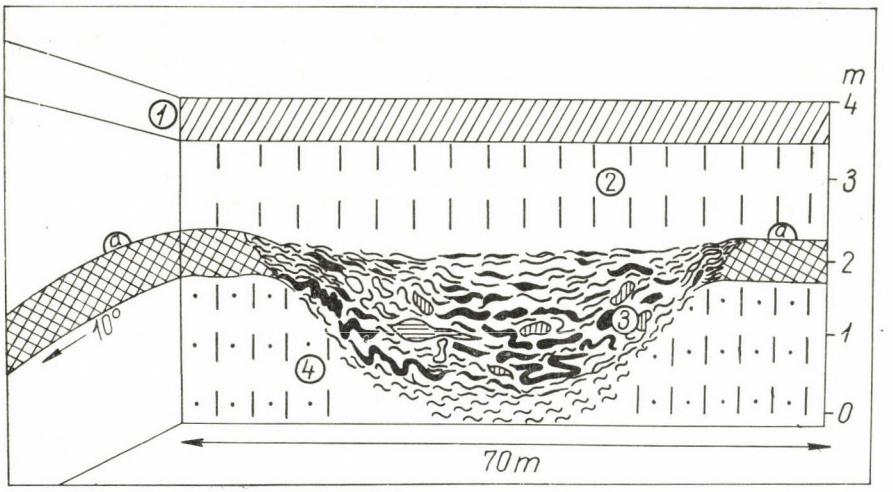

Fig. 3. Filled-up and buried minor derasional valley in the hummocky region of Southern Transdanubia. 1 — Brown earth with clayey illuvions ("Parabraunerde"), 2 — Loess, 3 — Solifluctional deposit (fossil adobe zone, concretions, limestone disks, chaotically kneaded sandy-loamy deposits)

valleys, but recent linear erosion does not leave any recognizable traces either. Nevertheless, the removal of the derasional deposits sometimes proceeds at quite a fast rate, as proved by observations concerning waste discharge, short-lived incisions on the valley bottom and residual alluvial cones, etc. These periodically arising minor forms are, however, easily effaced by deflation or by areal processes that are intensified by human activities.

The traces of linear erosion in the periglacial derasional valleys of the Pleistocene could have been effaced in a similar way, particularly because

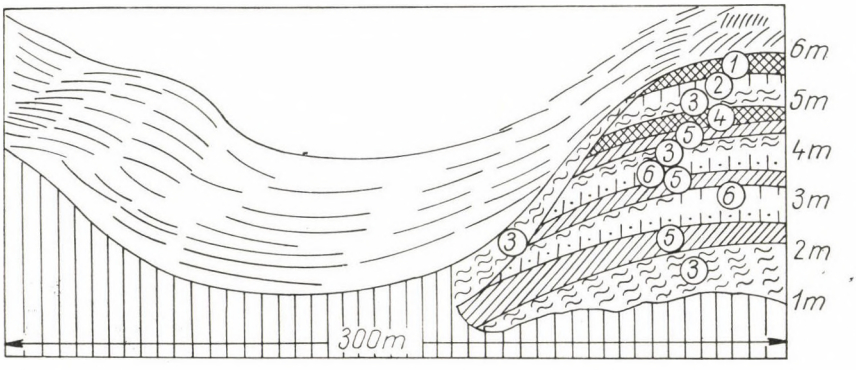

Fig. 4. Derasional valley once filled with a variety of fossil soils extending into the derasional deposits and scooped out subsequently. Hummocky region of Southern Transdanubia. 1 — Chernosem-brown forest soil, 2 — Loess, 3 — Loessy derasional deposit, 4 — Fossil chernosem-brown forest soil, 5 — Fossil chernosem-type soil, 6 — Sandy loess

in the duel of the areal and linear processes the climatic and local conditions of those times strongly favoured the areal mode of landscape sculpture.

Broadly speaking, the removal of the valley fillings exclusively by gravitational creep of the soil and talus, solifluction, mudflows or pluvionivation, with linear erosion practically absent, must have been restricted to the relatively steep and short derasional valleys of small drainage area, scooped out of slopes of relatively strong relief energy (PEJA 1959, SZÉKELY 1961, PINCZÉS 1960, PÉCSI 1961; Fig. 3). In these instances the movement of the scree was of the areal kind on the valley bottom as well as on the slopes.

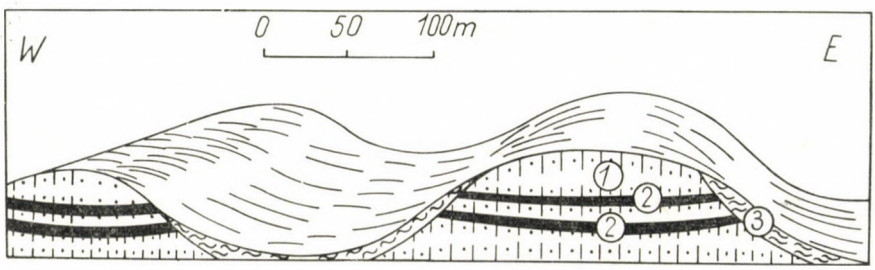

Fig. 5. Young (Recent) derasional valley in the hummocky regions of Southern Transdanubia. 1 — Sandy loess, 2 — Fossil reddish-brown adobe zone (B horizon of brown-earth type soil), 3 — Slopewashed loessy sediment

Morphometric surveys aimed at the establishing of the morphological features of the derasional valleys of Hungary have lately been initiated (Figs. 6, 7), but the studies explaining in detail the history of evolution, the varieties, the conditions governing the development etc. of the derasional valleys of a given area are still few and far between. Within a given landscape the studies performed till today suffice to distinguish certain types, but the resulting classification is as yet rather generalized and not detailed enough. In the Zemplén Mountains PINCZÉS (1960) has distinguished *partially* and *fully developed* derasional valleys. In the basins surrounding the Northern Mountains A. SZÉKELY has emphasized the *cross section* of the valleys, aiming at the same time at an overall characterization of their form and aspect, when distinguishing derasional valleys of *tub*, *pan* and *basin* section besides asymmetrical derasional valleys and derasional depressions. The classification established by the present author is also based on the cross section (1963) with, however, a simultaneous attempt at a systematization from a different point of view reducing the complicated slope forms observed in the hummocky area south of Lake Balaton (Outer Somogy County) to a few *fundamental types* such as *concave*, *plain*, *stepped concave* and *stepped convex* derasional slopes. Such a classification, established originally only for a given region, could eventually be generalized to a considerable extent just for the reason of its being based

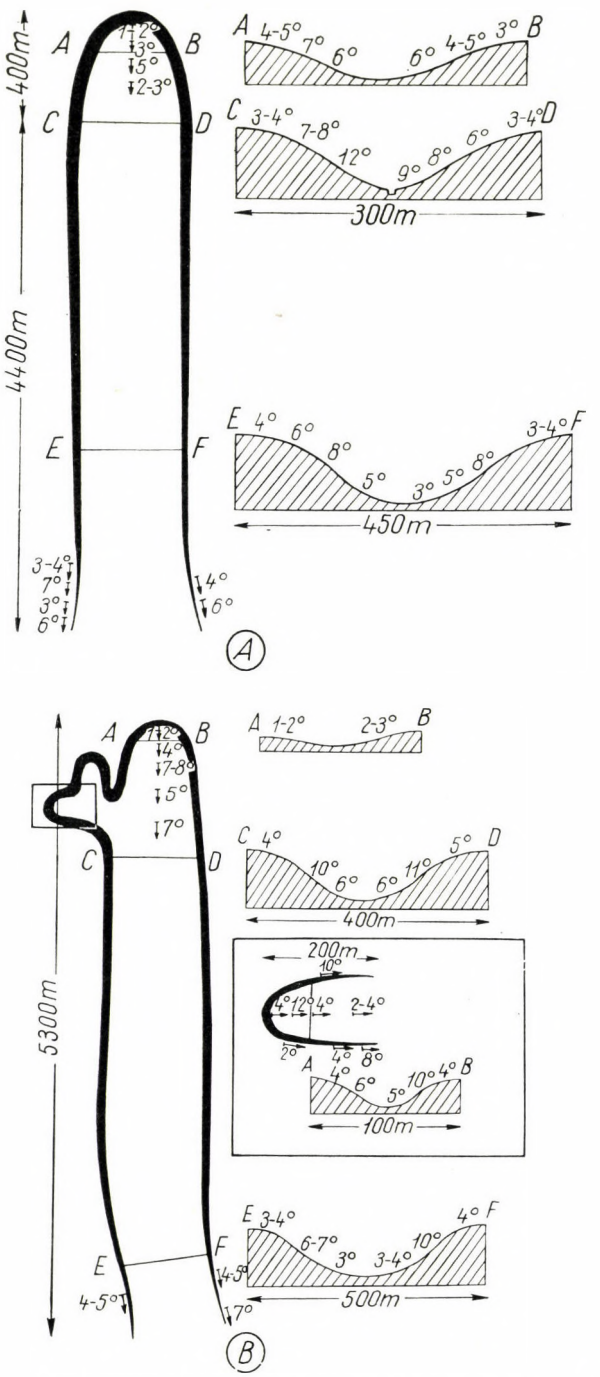

Fig. 6. Morphometric data of typical basin-shaped derasional valleys (A—B). (Transdanubian hummocks.)

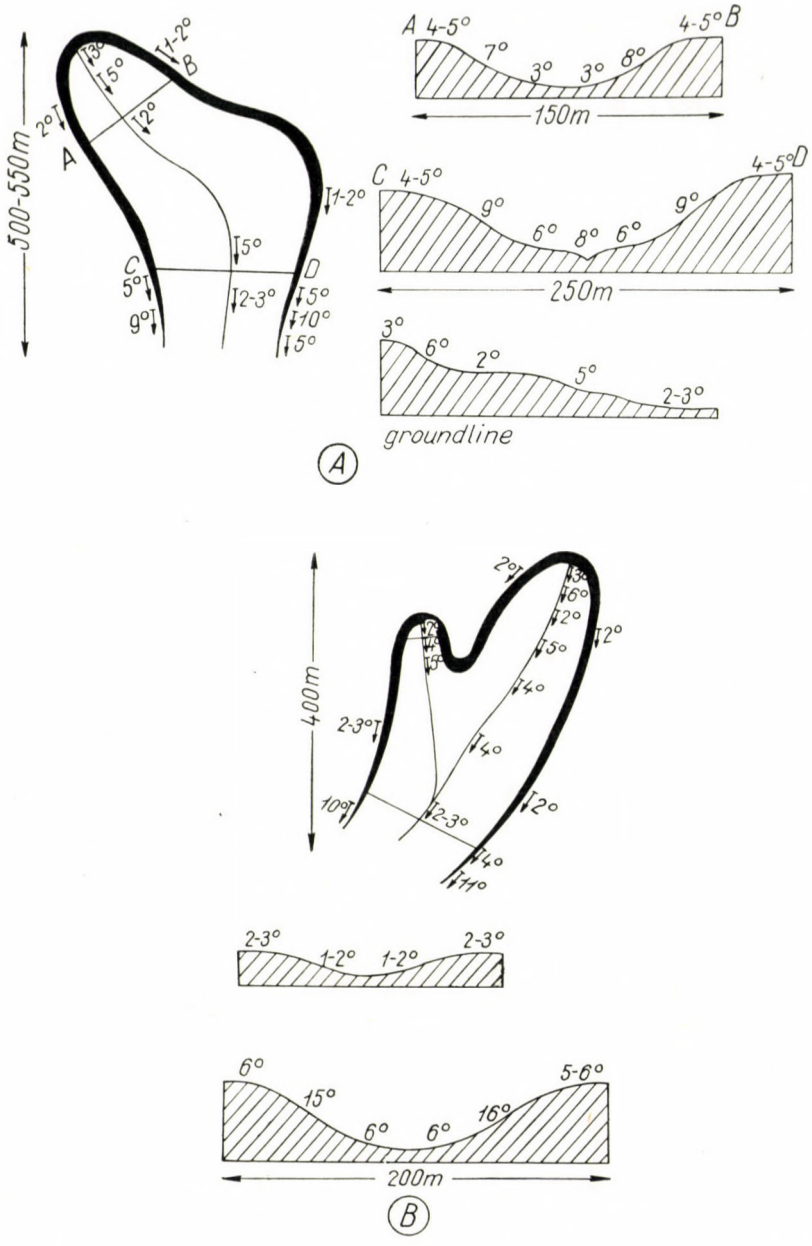

Fig. 7. Morphometric data of the valley-heads of typical basin-shaped derasional valleys (A—B). (Transdanubian hummocks)

on the fundamental types of slope. The author also attributes a considerable importance to the valley filling which is indicative to a high degree of the genesis and stages of evolution of the same, and — as far as this is possible within a classification of such a general scope — also of its age.

Classification is handicapped by several factors:

1. Besides the above-mentioned main morphological types of derasional valley, there occur elsewhere in the country numerous *transitional types* that cannot be placed into any one of the above classes.

2. *Asymmetric cross sections* of various types are also fairly abundant.

3. Morphometric forms of almost identical look may be *of widely different ages*. Pleistocene relics and quite young forms developed for their greater part under anthropogenic influences of almost identical nature and dimensions, have fairly often been observed alongside by side (Figs. 4, 5).

4. A number of derasional valleys — most of them Pleistocene relics — represent to-day a transition towards erosional forms as a result of Recent temperate climatic influence and belong rather to the category of *erosio-derasional valleys*.* The alternation of derasional and erosional features along the valley is also fairly frequent.

In Hungary the derasional and erosio-derasional valleys together dissect more than half of the piedmont and hilly surfaces and their importance locally exceeds that of the purely erosional valleys.

It was in these broad, flat depressions that in the Pleistocene most of the congelifractate talus and the sedimentary cover of the mountains and hills settled down in the course of its downslope migration. The derasional processes taking place in these valleys further played an important part in the evolution of the obliquely truncated *Pleistocene* piedmont slopes of the marginal regions of the mountains and hills.

REFERENCES

ÁDÁM, L.: A Szekszárdi-dombvidék kialakulása és morfológiája. (Evolution and morphology of the hummocks around Szekszárd.) Földrajzi Tanulmányok. Akadémiai Kiadó, Budapest, 1964. — BULLA, B.: Földrajzi Közlemények **67,** 268—280, 1939. — BULLA, B.: Általános természeti földrajz. (General physiography.) Tankönyvkiadó, Budapest, 1954. — BULLA, B.: Magyarország természeti földrajza. (The physiography of Hungary.) Tankönyvkiadó, Budapest, 1962. — BÜDEL, J.: Klimaheft, Geologische Rundschau **34,** 482—519, 1944. — BÜDEL, J.: Würzburger Geogr. Arbeiten **48,** 1—45, 1960. — MENSCHING, H.: Göttinger Geogr. Abhandlungen **14,** 1—51, 1953. — MAROSI, S.: Földrajzi Értesítő **1,** 60—67, 1962. — PATAKI, J.: Dunántúli Tudományos Gyűjtemény **25,** 26—44, 1961. — PEJA, GY.: Adatok az agyagos-homokos területek felszíni formáinak ismeretéhez. (Contributions to the knowledge of the landscape forms of clayey and sandy areas.) Candidate's Thesis. (Manuscript). 1959. — PÉCSI, M.: Föld-

* A valley form of a cross section recalling a derasional valley with, however, an incision in the axial line, carrying a permanent or intermittent stream insignificant in volume as compared to the size of the valley, with a thin alluvial seam. In the erosio-derasional valleys areal slope sculpture and linear erosion occur in a near-equilibrium.

rajzi Értesítő **1,** 41—54, 1955. — PÉCSI, M.: A negyedkori korráziós folyamatok hatása a felszínalakulásra és az üledékképződésre Magyarországon. (Influence of the Quaternary corrasive processes on morphological evolution and on sedimentation in Hungary.) Academic Doctor's Thesis. (Manuscript). 1961. — PÉCSI, M.: Földrajzi Értesítő **1,** 19—35, 1962. — PÉCSI, M.: Földrajzi Értesítő **1,** 1—29, 1964. — PINCZÉS, Z.: A Zempléni-hegység déli részének természeti földrajza. (Physiogeography of the southern part of the Zemplén Mountains.) Candidate's Thesis. (Manuscript). 1960. — SCHMITTHENNER, H.: Zeitschr. f. Geomorphologie 1—12, 1925. — SZÉKELY, A.: A Mátra és környezetének kialakulása és felszíni formái. (Formation of the Mátra Mountains and their surface features.) Candidate's Thesis. (Manuscript). 1961. — SZILÁRD, J.: A Külső-Somogyi dombság felszínalaktana és gazdasági életének természeti földrajzi feltételei. (Relief of the hummocky region of Outer Somogy County and the physiographic conditions of its economy.) Candidate's Thesis. (Manuscript). 1963. — TROLL, C.: Geologische Rundschau **34,** 545—694, 1944. — TROLL, C.: Erdkunde **1,** 162—175, 1947. — WICHE, K.: Sitzungsber. d. Öst. Akad. Wiss. Math. Naturw. Kl. Abt. 1, **167,** 173—179, 1958

О ФОРМИРОВАНИИ ПЕРИГЛЯЦИАЛЬНЫХ ДЕРАЗИОННЫХ ДОЛИН В ВЕНГРИИ

Й. СИЛАРД

Резюме

В холмистых и среднегорных областях Венгрии совсем характерны корыто- или блюдообразные, так называемые деразионные долины, которые занимают больше чем две третьих от всей площади поверхности и не располагают ни постоянным водотоком, ни даже балками в подошвах долин. Изучение их было начато сравнительно недавно. В Венгрии соответствующие исследования, приведшие к их более детальному познанию, датируются только с 1955 г.

Благодаря новейшим детальным исследованиям выяснилось, что эти долины чаще наблюдаются в холмистых областях, сложенных рыхлыми породами, но они могут формироваться также в пределах среднегорий, на породах разной твердости, на галечниковых покровах и поверхностях террас. Следовательно, формирование рассматриваемых деразионных долин не приурочено к какому-нибудь определенному литологическому составу, а тесно связано в основном с климатико-морфологическими условиями.

Большинство деразионных долин Венгрии сохраняет останцы морфологических форм, обусловленных перигляциальным климатом плейстоцена. В голоценовое время сократились природные условия образования деразионных долин. Однако, под влиянием антропогенной деятельности соответствующие процессы ускорялись.

В формировании поперечных разрезов деразионных долин решающую роль играет соотношение параллельной склону площадной эрозии к деятельности линейной эрозии, действующей по простиранию долин самих. Для деразионных долин это соотношение благоприятствует площадным процессам, о деятельности которых свидечельствуют заполняющие долины осадки, наслоенные параллельно наклону бывших склонов долин.

В перигляциальных условиях формирование склонов долин осуществлялось на глинистых поверхностях за счет солифлюкции, на песчанистых поверхностях за счет обмывающей деятельности талых и дождевых вод (плювионивации). В расширении долин участвовали также и сколисения и усадки. Снос накопившихся в долинах отложений можно объяснить периодической деятельностью линейной эрозии, долговечных следов которой не сохранилось.

Классификация деразионных долин Венгрии еще не разработана до такой степени, чтобы можно было ее считать общепринятой. Пока что она ограничивается выделением типов долин в пределах отдельных ландшафтных единиц. Расширение исследований, посвященных деразионным долинам, обусловлено их важной морфогенетической ролью и разширяющейся деятельностью по составлению детальных геоморфологических карт.

PLEISTOCENE PERIGLACIAL LANDSCAPE SCULPTURE IN THE NORTHEASTERN HUNGARIAN MOUNTAINS

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The author gives a review of the periglacial forms of relief of the Northeastern Hungarian Mountains, based on an evaluation of previous research as well as on his own experiences. He proves the types and degree of evolution of the periglacial forms to depend on the position, elevation and lithologic-petrographic constitution of the mountains involved. On the slopes dipping in a southerly direction, towards the Great Plains, the comminution of the rocks as well as their redeposition was more intense than on the northern slopes. This circumstance enhanced the high-degree asymmetry, already existing before the Pleistocene, of the mountains. The chain of the Northeastern Hungarian Mountains consists of various types of volcanics and some Mesozoic limestone encircled by less thoroughly compacted Tertiary deposits. Every one of these rock types reacted in a different way to periglacial frost action. In the mountainous regions the presence of several peneplaned surfaces characterized by a variety of sizes and types of periglacial forms could be established. The present paper enumerates the remarkable periglacial features and phenomena characteristics of the individual surfaces of denudation. It deals with the factors influencing the evolution of the diverse types of block fields as well as with their influence on the development of larger-scale landscape forms. It presents the role played by the various types of talus slopes, talus and scree covers and processes of comminution. The author also touches briefly upon the periglacial evolution of the terraces and in more detail upon that of the alluvial fans, with particular emphasis on the differences in their structure, size and constitution as governed by peri- and interglacial climatic oscillations. He mentions in passing the periglacial forms developed on sands, and then goes on to discuss the types of loess and their role in landscape evolution. He presents the phenomena connected with flat and slopy tundras, terminating his review with a description of the principal types the levels of denudation and derasional valleys that came to exist in the periglacial phases.

The vertical zoning of the Northeastern Hungarian Mountains of 600 to 1000 metres elevation depends in the first place on its *geographic position, its height and on the properties of the rocks it consists of.* Situated between 47°40' and 48°30' of latitude north and extending from the antecedent valley gorge of the Danube at Visegrád to the valley of the Bodrog, the chain of the Northeastern Hungarian Mountains grades in the south directly into the Great Hungarian Plains. Its northern hinterland is, on the other hand, constituted beyond a string of broad, low, intensely denuded, hummocky Tertiary basins by the parallel chains of the Northwest Carpathians, whose altitudes (1500, 2000 2500 metres) increase towards the north. This situation, substantially influencing the climate and vegetation of our region today and in the course of the Pleistocene glacials, affected in consequence also the processes of periglacial landscape evolution. The taller mountains to the north further shortened the brief summers of the periglacial phases, thus rendering the climate cooler

but also slightly more humid than on the southern side. The southerly dry slopes looking down on the Great Plains were the sites of frequently alternating freeze-and-thaw, a circumstance that intensified congelifraction as well as comminution by insolation of the barren dark cliffs of rock up at the higher altitudes. Frequent freeze-and-thaw also played a part in accelerating the transportation of the scree by solifluction.

The Northeastern Hungarian Mountains exhibit a conspicuous asymmetry. In the north, the chain is limited by short but very steep slopes of 30 to 45°, in places even of 50 to 90°, whereas in the south the slopes are longer and much gentler in consequence. The main ridge is thus situated as a rule close to the northern margin of the chain. It was this combination of climatic, botanic and relief factors that resulted on the flatter southern side of the chain in a faster and more intense loosening of the deposits (mainly by frost, and to a lesser degree by insolation) and in a larger-scale removal of the loosened material (mainly by solifluction). Of course, comminution was just as intense in the course of transportation down the long southerly slopes. As a result, the detritus that was deposited in the southern foothills and piedmont areas filling up the northern part of the Hungarian Plains with enormous amounts of waste, largely belonged to the finer grain size classes. The coarse detritus of the short northern slopes had on the other hand no occasion to break up or wear away in any substantial degree in the course of its brief journey by gravity down the northern slopes of the mountains. *This process active in the Pleistocene enhanced the pre-existing asymmetry of the relief.* The southern slopes were intensely denuded and also flatened by the large-scale comminution and transportation of the debris whereas on the northern steep slopes the broken-up detritus moved by rockslides or slumps or just rolled downslope. Consequently the slope angles did not substantially change in the course of recession.*

The evolution of a certain set of periglacial forms in a certain region is also governed to some extent by the nature of the underlying rock. The Northeastern Hungarian Mountains largely consist of young Tertiary volcanics and to a lesser degree of Mesozoic and Palaeozoic sedimentary rocks, mainly limestone, both encircled by ill-consolidated Tertiary deposits. Every one of these types of rock reacted in its particular way to the influence of frost that, accordingly, brought about diverse degrees of comminution and weathering, diverse types of blockfields, and diverse rates of downslope transport.

* Let us emphasize that at present the breaking up of rock on the northern and southern slopes proceeds in exactly the opposite sense, because under present climatic conditions the alternation of freeze and thaw, more frequent on the northerly slopes, also covers a longer time each year, including also part of the spring and fall. Thus the larger-scale comminution of the rock is restricted today to the northern steep and consequently barren slopes. As a result, the fossil periglacial talus, spread in front of the northern slopes of the mountains, is covered today by a fresher, smoother Recent talus slope.

Further differences arose within each one of the above-mentioned three main types. Thus e.g. in case of volcanics there is a considerable difference between massive lava rock likely to be broken up into coarse fragments and the accompanying pyroclastics likely to be weathered into fine-grained products. There are further significant differences between andesite, highly resistant rhyolite and readily comminuted basalt. Another essential difference is connected with the intense hydrothermal activity subsequent to the volcanic eruptions that altered the andesite in wide bands, in some instances down

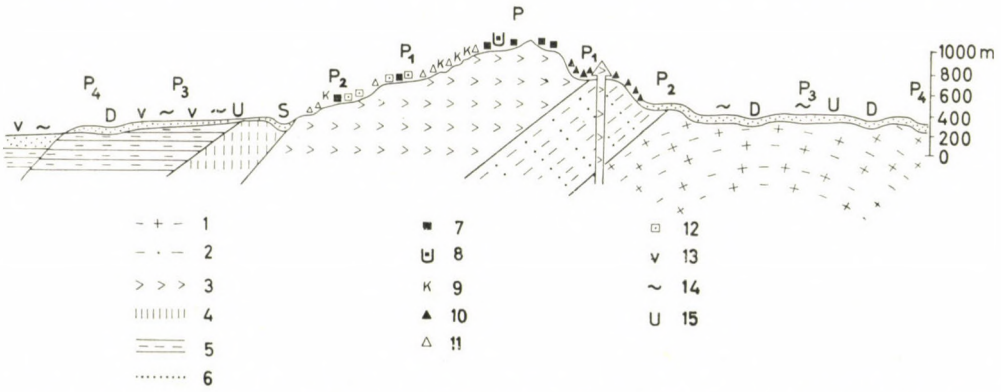

Fig. 1. Generalized profile of the levels of denudation of the volcanic units of the Northeastern Hungarian Mountains, showing the periglacial phenomena. 1 — Oligocene deposits (clay, sand, sandstone), 2 — lower Miocene deposits (clay, sand, gravel), 3 — middle Miocene andesite, tuff and agglomerate, 4 — Sarmatian deposits (clay, marl), 5 — Pannonian deposits (clay, sand), 6 — Pleistocene derasional deposits, 7 — periglacial boulder fields, 8 — stone polygons, 9 — cryoplanated levels, 10 — talus slopes, 11 — scree covers, 12 — boulder walls, 13 — ice veins, 14 — guirlanded soils, 15 — clay bags. P — Sarmatian peneplane, P_1 — lower Pannonian peneplane ledge, P_2 — upper Pannonian peneplane ledge, P_3 — upper Pliocene piedmont level, P_4 — lower Pleistocene piedmont level, S — piedmont basin, D — derasional valley

to kaolinitic end products. On the other hand, the rock was impregnated elsewhere with silica by hot springs, which also deposited hot-water quartzite locally. These hard silicified andesites and hydroquartzites are highly resistant to weathering. Consequently, they were mostly broken up into large-sized debris constituting fine examples of blockfields. The more or less altered pseudo-agglomerates (Szádeczky-Kardoss 1959) are likely to decompose, while their fresher bands are also liable to fragmentation.

From the point of view of periglacial denudation, the Tertiary deposits around the mountains can be grouped in three classes: *a)* deposits suited to transportation and denudation by solifluction, such as clay, marl, sandy clay and the "Schlier" facies. *b)* Rocks mainly deteriorated by congelifraction: upper Oligocene sandstones. *c)* Deposits sensitive to sheetwash: various sands.

Periglacial phenomena exhibit a certain dependence also on altitude (Fig. 1.). The author pointed out lately (Székely 1965) that the Northeastern

Hungarian Mountains are dissected by several levels of denudation of varied age and elevation and that to every one of these levels a particular set of physiographic conditions can be ascribed. This vertical zoning is also apparent in the distribution of the periglacial phenomena.

According to the latest results in this field (PINCZÉS 1960, SZÉKELY 1960 a, b, 1964) the relief and the physiographic forms of the Northeastern Hungarian Mountains evolved upon a climatic peneplane developed by subtropic areal erosion in the Sarmatian stage of the Miocene. The peneplane

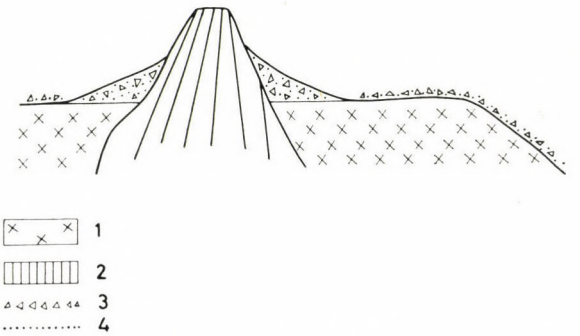

Fig. 2. A volcanic pipe jutting out of the mountaintop peneplane, surrounded by a talus slope. 1 — andesite, 2 — younger andesite constituting the pipe, of columnar parting, 3 — coarse andesite detritus, 4 — fine andesite detritus and products of weathering

was uplifted in several steps in the course of the Pliocene and of the Quaternary. This stepwise uplift resulted under the important climatic changes that took place in the meanwhile in the evolution of peneplane and piedmont ledges and piedmont levels of various elevation, age and type. We shall now treat the periglacial phenomena of the Northeastern Hungarian Mountains in the order of these levels, emphasizing their vertical zonality.

1. Frost action resulting in the evolution of *block fields* was most intense in the central, highest part of 800 to 1000 metres elevation of the mountains, a zone that in its original state represented a Sarmatian "Rumpffläche" surface. On the plateaux of this height large boulders of rock are everywhere seen to jut out of the soil whereas on the marginal parts of the plateaux the thin soil cover reveals more often than not a blockfield strewn all over the surface. The most intense blockfield formation was, however, centered on the peaks and ridges elevated above the plateaux. The peaks of gentler slopes, in their majority the remnants of ancient volcanoes, are coated in a thick mantle of debris whereas the steeper ones, especially the volcanic necks of columnar jointing, are surrounded by a wreath of massive boulders (Fig. 2). This most intensely comminuted topmost zone was at the same time the principal source of feed of the lower-lying zones. Up there the gentler slopes

of 5 to 15 degrees are still covered almost everywhere with thick scree that preserves the underlying rock from further weathering whereas the northern steep and barren slopes offer even today a point of least resistance to comminution. Recent fracturing of the rock is insignificant except on the barren slopes of considerable elevation steeper than 30°. On these high remnants of former plateaux one observes locally boulders of various size standing on end in roughly hexagonal patterns. These features are the vestiges of the largest-size *boulder polygons* of this country. On the slopes these polygons are seen to sretch into strings of boulders. On the gentler slopes of the marginal parts of the plateaux, large stone bags, 2 to 3 metres deep, are seen to occur, consisting of circularly arranged big blocks forming a regular bag-shaped depression. The filling of these bags is coarse detritus as opposed to that of the gravel bags. The southerly slopes of the high plateaux exhibit the finest and best-developed specimens of cryoplanated ledges.

Summing up the above-enumerated features we may state the high plateaux to have undergone an intense denudation and reshaping in the Pleistocene periglacial period.

2. The peak level of the mountains is accompanied by *two narrower ledges of denudation* evolved, as suggested by their elevation as well as by the corresponding deposits, in the lower Pliocene (SZÉKELY 1964, 1965). The upper ledge of 600 metres elevation is presumably connected with the lower Pannonian, the lower one at the height of 400 metres with the upper Pannonian. These two horizon stogether constitute the middle zone, intensely dissected by the valleys and preserved at best in the form of mountain tops and side ridges of constant altitude. Comminution was less intense at this level than on the top. This zone received from above large amounts of detritus, which particularly near the inner edge of the ledges was incorporated into the material of the local blockfields. By the time it arrived in the middle zone, the detritus of the top horizon underwent further weathering that considerably diminished its grain size and thoroughly mixed it with loamy substances and with finer debris and dust produced by cryofraction. The pure blockfields of large blocks, frequent at the top horizon, are in this zone restricted to the marginal parts of the ledge and to the peaks and volcanic vents emerging from it; the former are usually the sources of boulder sheets reaching down the steep slopes of the valleys. The stone polygons and cryoplanated ledges occuring on the broader plateau-like mountain tops of this zone are smaller than those of the horizon above. The most characteristic features of the middle zone are walls of loosely compiled boulders, of 3 to 4 metres height, 8 to 10 metres width and 70 to 150 metres length traversing the ridges and plateaux. The boulders are of local derivation, their interstices are unfilled by finer products of weathering and contain only some little detritus. These walls are presumably congelifractate vestiges of ledges of hard rock once rising above the surface. The freezing of

water that seeped in between the banks of hard rock must have broken up the larger units.

3. The *lowest zone* descending from 300 to 200 metres is the broadest and best-developed (Fig. 1.). Also the age of its evolution is most satisfactorily proved as the surface is incised into the Tertiary deposits including the upper Pannonian, being in its turn dissected by the Quaternary valleys. It is consequently relegated to the upper Pliocene (SZÉKELY 1960, 1964, 1965). According to PÉCSI (1963) this surface is *a piedmont* developed in the drier semiarid phases of the upper Pliocene. It is likewise dissected by the outward-radiating valley pattern, but to a smaller extent only. The shallower, broader valleys are separated by broad, flat divides. Whereas the upper horizons mostly developed on massive volcanics and limestone, the piedmont reposes at best in its highest parts on hard rock; its greater part was sculpted out of loose Tertiary deposits (clay, sand, marl, loose sandstone).

Periglacial processes and forms at this level are widely different from those higher up. Congelifraction is subordinate, and the blockfields so characteristic of the more elevated levels are absent. Most of the detritus derived from the upper zones is thoroughly comminuted. The occasional boulders of head to table size are not removed farther than a couple of hundred metres from the directly adjacent steeper slopes (Fig. 2.). Particularly near to where the larger valleys emerge from the mountains, loam covers, rich in andesite boulders of several metres diameter, are fairly widespread.

The southern piedmonts are characterized by large amounts of finer-grained debris bedded into abundant products of weathering, whereas in the north the detritus is coarser and uncontaminated by finer products. The larger blocks did not get farther than some hundred metres off the base of the slopes, either. In the course of subsequent transportation by solifluction, the boulders were mixed here, too, with clay and loam. Thus boulders of fist size bedded in clay could move as far as 7 to 8 kilometres on both sides of the mountain. The piedmont itself bears, however, the imprint of intense solifluction. The detritus received from higher up was immixed into the finer, pelitic matter of the piedmont, and moved along under the influence of regelation. A further important factor of denudation was the slopewashing activity of the strong summer rainstorms. The lowest step was consequently sculpted in the periglacial phases by processes of derasion — solifluction and pluvionivation — over its entire surface.

The lower parts of the piedmont exhibit an increasing thickness of *loess-like deposits*. On the northern flank of the mountains this type of deposit is generally richer in clayey products.

On the piedmont, where the processes of derasion dominated, a motley set of *derasional forms* came to exist, including certain types of valleys which dissected the piedmont surface into a series of hummocks. The derasional

valleys are separated either by broader elevations, or by steeper ridges (Figs. 3 and 4) ornamented by a diversity of derasional cones, pyramids, coffin-shaped forms and low cols (SZÉKELY 1960).

Along the valleys there are in the south broad cryoplanated ledges proceeding uninterrupted through considerable distances, as much as one to two kilometres. Also in the north, these ledges are dissected by derasional valleys. The ledges situated higher up are covered by 2 to 4 metres, the lower-lying ones by 6 to 7 metres of loam, clay, sandy clay, and stratified slope loess redeposited by solifluction from the piedmont surface above.

From the point of view of the derasional deposits, three zones can be distinguished in the belt of the lowest broad piedmont surface (SZÉKELY 1960). The higher elevations are the source areas of the deposits; on them, denudation was dominant and the derasional-deluvial cover is absent or very thin (one metre). The lower parts of the elevations and the upper parts of the valley flanks are the areas of transit that received a large volume of slope deposits from above but passed on most of it to the lower-lying levels. Consequently they are covered to-day by no more than two to four metres of late Würm deposits. Finally the parts of the slopes below the line of inflexion, the low-lying terraces, and particularly the straths and valley bottoms are the sites of derasional accumulation. The thickness of the deluvial series is as a rule 6 to 12 metres, but in the south near the basin it increases to as much as 30 to 35 metres, including also some interglacial deposits and fossil soil horizons.

4. The aforementioned level of accumulation in the valleys constitutes the *lowermost level* of the Pleistocene basin and valley system. These basins and valleys are incised into an early Pleistocene piedmont surface, whose broad backs were mostly sculpted by processes of derasion. In the plains the foreland of this piedmont surface is built up besides derasional deposits mainly of the coarse gravel of alluvial fans and alluvial-fan terraces deposited by the rivers which emerge from the mountains. The rivers repeatedly incised themselves into this surface as a result of the stepwise subsidance of the basin and developed in consequence a conspicuous system of alluvial fan terraces.

Systematic classification of the most characteristic periglacial phenomena of the Northeastern Hungarian Mountains

1. *The periglacial blockfields* are in their majority the results of dominant congelifraction and subordinate insolation in situ, that is, the products of an essentially climato-morphologic process. Their evolution proceeded at a faster rate in the south, for in the periglacial phases the alternation of freeze and thaw

was more frequent on the southerly slopes. However, the blockfields are lithomorphologic phenomena as well, as they are restricted to massive rocks much more liable to break up than to decompose. A factor influencing their evolution was the banking of the rock, since comminution could proceed faster parallel than perpendicular to the banks. Widespread and characteristic in the volcanic mountains, they are subordinate on the limestone fault blocks, as limestone is bound to break up into much smaller-sized debris.

Lately the author made an attempt at a morphogenetic classification of the blockfields of the Hungarian volcanic mountains (SZÉKELY 1960). He succeeded in proving the close correlation between the nature of the underlying rock and the forms evolved on its surface. On volcanic rocks the following types of blockfield could be distinguished: *a)* the blockfields constituted by *huge blocks* developed on thick-banked andesite sheets, thick-banked basalts and on rhyolites; *b)* the *slab fields* consisting of thinner and more fragile slabs of andesites and basalts of platy parting, *c)* the *boulder fields* developed on andesites of spheroidal weathering, mostly on pseudoagglomerates. Of course, a blockfield long exposed to weathering is further comminuted in situ but this is relatively rare as in most cases comminution occurs jointly with the removal of the detritus downslope. The removed detritus then forms talus or scree slopes, and in its place a new blockfield comes into existence.

In Hungary J. KEREKES was the first to have attacked the problem of the blockfields (1941). KEREKES held all blockfields in the Hungarian mountains to be periglacial, although he emphasized the difference between sharp-edged, fresh, uncovered, and worn, weathered, soil- and vegetation-covered types. These differences indicate, however, that the formation of blockfields goes on even today on the elevated barren surfaces, particularly where the structure and texture of the rock is favourable, e.g. where the banks on the rock can be attacked laterally.

The geomorphological importance of blockfield formation is much greater than formerly believed. First of all, it is the source and feeder of the entire range of periglacial deposits from the large blocks through the talus slopes and finer scree down to the finest loamy layers. Owing to its striking aspect, *it lends a conspicuous periglacial look* to the surfaces it covers, even to the old Tertiary peneplanes. Blockfield formation *substantially contributed* also *to the evolution of large-scale landscape forms*, because on the flat or concave parts of the Tertiary peneplanes or peneplane ledges the process of blockfield formation, nowhere deeper than about five metres, tended to preserve the underlying peneplaned surface. On the more widespread convex slopes, however, solifluction was bound to remove gradually the blocks and boulders, practically at the rate of their formation, thus bringing about a considerable lowering of the original surface (peneplane remnants periglacially denuded and sculptured, Fig. 5).

2. *Talus slopes.* Transported by gravity down slopes steeper than 30°, the talus leans with straight slopes as steep as 25 to 37° against the even steeper original slope, thus giving rise to a broken slope profile. The talus is to some extent sorted, the larger boulders being accumulated downslope. The finest examples occur in those places where the detritus is relatively fine, in the first place in limestone and particularly dolomite areas, where the talus slopes of the two opposing flanks of the narrower and drier valleys may meet in the middle (Fig. 3.). The talus-slope phenomenon also occurs on the steeper flanks of the volcanic mountains in Hungary, particularly on those slopes where the banks are exposed edgewise (Fig. 5). Detritus arrives on these slopes in the

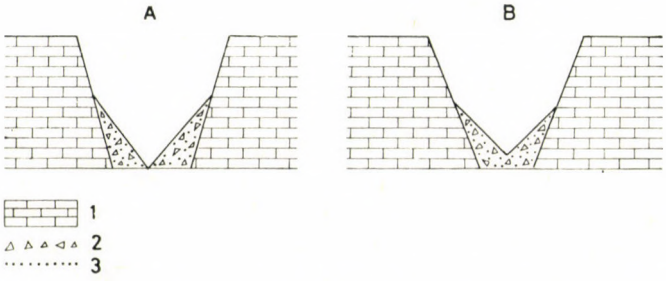

Fig. 3. Scree slopes in the valleys of a limestone region. *A* — in a broader valley carrying a permanent stream; *B* — in a narrower dry valley. 1 — Mesozoic limestone, 2 — coarser scree, 3 — loam

form of largish sharp blocks and is further comminuted in situ. In the periglacials, part of the products of this process was removed by solifluction. What was left in place, underwent in the warmer and rainier interstadial, interglacial and postglacial phases a fairly intense weathering. On these more or less barren slopes steeper than 30°, detritus is still being formed although at a considerably slower rate. In this latter case the weathered debris mixed with yellow clay, loam and subsoil is overlain by sharp angular scree not mixed with soil and lacking a vegetal cover. The author succeeded in proving the Holocene age of these latter by comparative measurements. In the Hungarian volcanic mountains it is in particular the pipes of andesite jutting steeply out of the top level and the higher ledges whose lower parts exhibit well-developed talus slopes (Fig. 2).

A task still to be carried out is the exploration of the thicker talus slopes of every description by means of trenches and pits. Besides the deposits in the caves, it is these profiles that promise the most interesting evidence as to the Pleistocene chronology of the Hungarian mountains.

3. On the gentler slopes gravity in itself was insufficient to assure the removal of the comminuted rock debris. The most efficient process of transpor-

tation down this type of slope is *solifluction*, slow-moving but displacing huge volumes of material over fairly large areas. Whereas the detritus displaced by gravity is accumulated on the bottom of the slope without any contamination, the scree mainly transported by solifluction is kneaded into the soil. The characteristic trait of the scree sheet is consequently the absence of any definite structure; it consists of a mixture of unsorted, angular or slightly worn detritus with soil, loam and/or yellow clay. In the Northeastern Hungarian Mountains two main types of scree sheet can be distinguished. The one is a coat of loam bearing little detritus. The other type invariably contains one or two horizons of detritus, or even some gravel farther off the steeper slopes. The former type is thinner (two to four metres thick), but both may grow much thicker near the valley floor and the piedmont, respectively. The strings of detritus imbedded in the loam are presumably the products of the coldest spells of the glaciations. On the steeper slopes, deforestation resulted frequently in the wearing away of the scree cover by soil erosion.

4. *Boulder flows.* The detritus constituting this type of feature is more worn than that of the scree sheets; the edges of the stones are rounded. The spaces between the boulders are empty or contain but little finer detritus. The boulder flows frequently present a tortuous outline reminding of the course of a stream. At the time when these flows last moved, the interstices of the boulders must necessarily have been filled with products of alteration, especially loam. Of this filling little is left over to-day, most of it having been washed out by the swift torrential waters of the rainstorms. As a result they are found to-day in best preservation on the gentler slopes surrounding the valleyheads, on the slopes of saddles and cols, and particularly on the bottom of short broad valleys carrying no perennial stream. In this last instance the boulder flow may be especially thick and well-developed (Photo 6.). One can observe even to-day the removal of the finer sediment from between the boulders by the brawling waters of an occasional shower.

5. The huge volume of detritus deposited in the valleys by gravity and solifluction could not be removed in the dry periglacial phases by the rivers of considerably diminished discharge. In consequence the valley floors received a thick cover of alluvium; in the subsequent rainier spells the swollen rivers incised themselves into this filling and carved *terraces* out of it. The terraces are of course not exclusively periglacial features although the alternation of the glaciations and interglacials strongly promoted their evolution (BULLA 1939, 1962). The predominantly periglacial deposition of the terraces is proven by the fact that the well-developed system of terraces along the rivers of the northeastern mountainous region of Hungary (Zagyva, Tarna, Eger, Sajó, Hernád) has yielded exclusively glacial faunal assemblages.

6. *The alluvial fans*, not exclusively periglacial, either, but likewise favoured by periglacial conditions, constitute today a vast field of coalesced

fans in the foreland of the mountains in a length of more than 100 kilometres. In the periglacial phases the thinly trickling streams could of course not spread the coarser detritus over as extended areas as are covered by the finer sediments discharged by the more voluminous streams of the wetter interglacial phases. The periglacial phases are consequently characterized by smaller but steeper alluvial cones (Fig. 4.). The wetter phases of weathering and loam formation

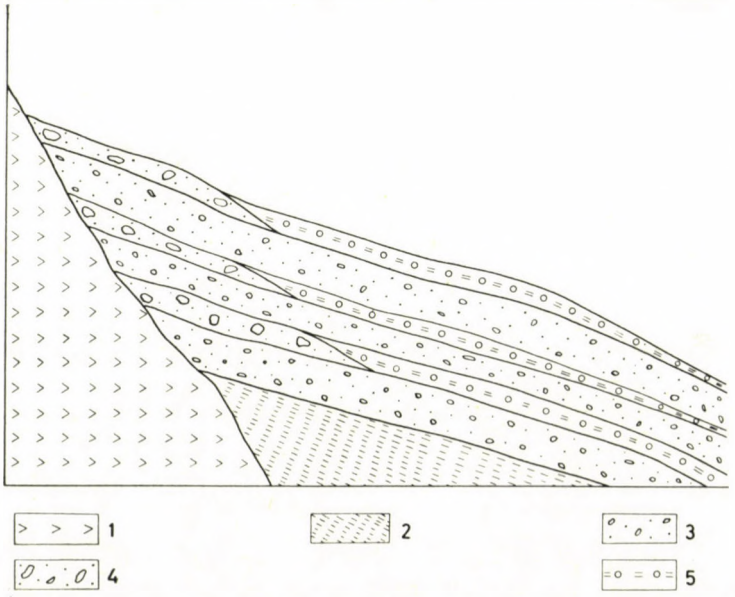

Fig. 4. Generalized profile of the alluvial fans of the piedmont. 1 — middle Miocene andesite, 2 — upper Pannonian clay, 3 — fine alluvium (gravel, clay), 4 — coarser alluvium (boulders, sand), 5 — material reworked by solifluction (gravel, clay)

are indicated on the alluvial fans by more widely spread and more intensely rolled gravel and finer sediment. This distinction permits to separate the glacial and interglacial horizons within the alluvial-cone deposits.

Also the study of the horizontal changes in alluvial-fan deposition may furnish some interesting results. Even in periglacial times the waste grew rapidly finer with increasing distance from the mountain. The thin periglacial streams could not move the gravel-size alluvia very far, whereas in the interglacial phases and in post-glacial times smaller amounts of finer and intensely rolled gravel could travel fairly great distances in the larger rivers. Thus at a distance of a few kilometres off the mountains, the situation is reversed, the inter- and postglacial alluvium being coarser than its periglacial counterpart. All the gravel deposited in the glacials so far from the mountains had been moved by solifluction.

7. The gravel fans are accompanied in the south by a series of *sand fans*, formed partly under periglacial, partly under interglacial conditions. Their surface reveals some sculpture by the wind in the periglacials of sparse vegetation and in the post-glacial hazel phase. The wind-blown elements of the relief are fairly inconstant, those of to-day date back no farther than the dry warm hazel phase of the early Holocene.

8. Finally the *finest-grained group of periglacial deposits* is constituted by loess and loess-like deposits. B. BULLA (1939, 1963) was entirely right when he called this type of deposit the most characteristic and most widespread periglacial formation of the Carpathian Basin. Until lately most of the loess was considered aeolian in origin. Detailed studies performed in the last few

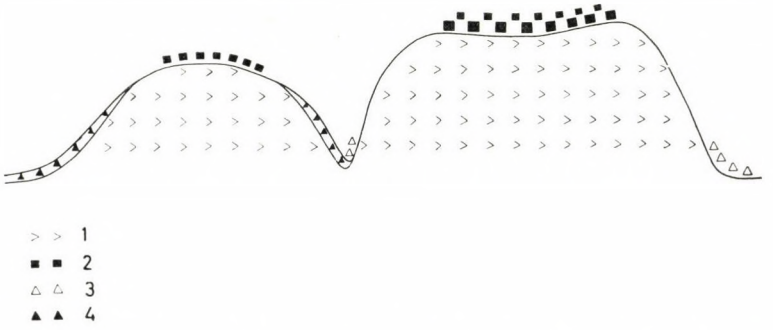

Fig. 5. Concave surfaces conserved by blockfields while the convex slopes were denuded. 1 — andesite, 2 — blockfield, 3 — talus slope, 4 — scree cover

years have, however, proved most of the loess to be finely stratified, reworked by processes other than aeolian (PÉCSI 1961, SZÉKELY 1960). The more or less regularly alternating fine layers frequently contain intercalations of detritus, fine debris and sand, particularly close to the mountains. Their stratification is invariably parallel to the slope of the relief. Absent on the higher divides, the loessy deposits gradually thicken towards the lower-lying areas, attaining maximum thickness along the outlines of the basins and valleys, particularly near the mouths of the smaller tributaries. The upper limit of extension of the loessy deposits lies higher in the east, because the scantier precipitation in that region shifted the lower forest limit farther upslope. In the west the highest loessy deposits occur at an altitude of 250 m, in the east of 400 metres, substituted above by varieties of loam formed under more abundant precipitation. The grain size distribution of these loess-like deposits recalls that of the typical loess but the fine stratification suggests a formation by sheetwash or soil flow or creep in the thin liquid layer over a frozen subsoil (PÉCSI 1961). Most of the material constituting these deposits is of a nearby derivation, also their heavy mineral assemblage reflects the composition of the rock

cropping out farther up, but some aeolian dust is also invariably present. The loess-like deposits may stand up in vertical walls just like typical loess; these walls are seen to be interrupted by layers of a variety of fossil soils. Also their relief-smoothing effect suggests that of typical loess; moreover, in the case of these slope loesses the filling of the depressions is accompanied by the slow but persistent wearing away of the elevations and slopes, a process absent in the case of true loess. Slope loess differs from unstratified true loess by its stratification, slightly coarser grain size, lower lime content, scarcer limy concretions. The substance is less homogeneous, contaminated, mixed with extraneous elements. The stratification consists of the alternation of more clayey and more sandy layers of millimetre thickness.

The above-described distribution in space of the formations ranging in grain size from large boulders to fine loessy particles is seen to possess a well-defined zonality. On the other hand, flat- and slopy-tundra forms are ubiquitous, although they are not exactly the same everywhere. The stone bags of the higher levels are substituted by clay bags on the piedmont surfaces, gravel sacks on the gravel terraces and various forms of sand bags on the sand fans. On the other hand, these polygonal and baggy forms are absent from the coarser gravel surfaces of the creek terraces and of the gravel fans.

The cryoplanated ledges are as a rule narrower and shorter on the harder rock of the higher levels. Their evolution is due principally to congelifraction, whereas the broader and longer cryoplanated surfaces of the piedmonts are mostly due to solifluction. The formation of larger frost wedges and smaller frost cracks is largely restricted to the less compacted clayey, sandy and gravelly deposits of the lower levels. Among the diversity of ground frost forms of the clayey and sandy-clayey surfaces, the guirlanded, string-of-pearl, sheaf- and comb-like forms should be mentioned. In the areas not touched by Holocene erosion, these forms are seen to be overlain everywhere under Recent soil by a stone pavement formation or by a thin string of gravel deposited by solifluction (PÉCSI 1961), marking the end of the Würm. Their absence helps to establish the depth of Holocene erosion.

The periglacial landscape forms of greatest extension are *the broad piedmont surfaces* and levels of derasion (PÉCSI 1964) and the various products of *derasional landscape* sculpture (SZÉKELY 1960), of which latter the derasional valleys indicating no trace of any perennial stream are the most conspicuous. The combination of forms depends at any point of the surface on the large traits of the relief, on exposition and on the nature and structure of the underlying rock.

As a conclusion we are justified in stating that the Northeastern Hungarian Mountains, abounding in periglacial phenomena and forms, belonged to the true periglacial zone. Research has established a well-defined vertical zonality of these periglacial forms (Fig. 1.). The small and medium-sized ele-

ments of the landscape of to-day are chiefly of periglacial origin; also the large forms were profoundly modified by periglacial processes. The fact that the periglacial forms and deposits which are visible to-day all originated in the last Würm glaciation shows that periglacial landscape sculpture was very intense, indeed. The total effect throughout the Pleistocene was obviously many times as strong. (Photo 1—6.)

Photo 1. Upper Pliocene piedmont surface in the foreland of the Mátra Mountains

Photo 2. Boulder field displaced by solifluction at the southern foot of the Mátra Mountains

Photo 3. Derasional valley of flat basin-shaped cross section scooped out of the piedmont surface with a derasional ridge in the background

Photo 4. Basin-shaped derasional valley scooped out of a sandstone surface on the piedmont, with a derasional ridge in the background

Photo 5. A talus slope consisting of andesite in the Mátra Mountains

Photo 6. A boulder flow in a minor dry valley on the southern side of the Mátra Mountains

REFERENCES

BULLA, B.: Földtani Közlöny **67,** 196—215, 289—309, 1937. — BULLA, B.: Földrajzi Közlöny **67,** 268—281, 1939. — BULLA, B.: Földrajzi Közlöny **69,** 199—230, 1941. — BULLA, B.: Magyarország természeti földrajza. (The physiography of Hungary.) Tankönyvkiadó, Budapest, 1962. — BÜDEL, J.: Erdkunde **7,** 249—266, 1953. — KEREKES, J.: Földtani Int. Jel. Beszámoló III. 97—166, 1941. — KÉZ, A.: Peterm. Geogr. Mitt. **83,** 253—256, 1937. — LÁNG, S.: A Mátra és a Börzsöny természeti földrajza. (Physiography of the Mátra and Börzsöny Mountains.) Akadémiai Kiadó, Budapest, 1955. — LÁNG, S.: Földrajzi Közlemények **2,** 78, 21—64, 1953. — MENSCHING, H.: Zeitschr. f. Geomorph. **2,** 165—186, 1958. — PÉCSI, M.: Földrajzi Közlemények, **9,** 85, 1—24, 1961. — PÉCSI, M.: Földrajzi Értesítő **11,** 19—39, 1962. — PÉCSI, M.: Földrajzi Közlemények, **11,** 87, 195—212, 1963. — PÉCSI, M.: Földrajzi Értesítő **13,** 1—29, 1964. — PINCZÉS, Z.: A Zempléni-hegység déli részének természeti földrajza. (Physiography of the southern part of the Zemplén Mountains.) Candidate's Thesis, 1960. SZÁDECZKY-KARDOSS, E.: Földtani Közlöny **66,** 213—228, 1936. — SZÁDECZKY-KARDOSS, E.: M. Tud. Ak. Műsz. Oszt. Közl. **23,** 385—410, 1959. — SZÉKELY, A.: Földrajzi Közlemények **8,** 84, 251—284, 1960. — SZÉKELY, A.: A Mátra és környezetének kialakulása és felszíni formái. (Evolution and landscape forms of the Mátra Mountains and their vicinity.) Candidate's Thesis 1960. SZÉKELY, A.: Földrajzi Közlemények **12,** (88), 199—218, 1964. — SZÉKELY, A.: Acta Geographica 1965. (In press.)

ФОРМЫ ПЛЕЙСТОЦЕНОВЫХ ПЕРИГЛЯЦИАЛЬНЫХ ОТЛОЖЕНИЙ СЕВЕРНОГО СРЕДНЕГОРЬЯ

А. СЕКЕЛЬ

Р е з ю м е

На основании оценки результатов исследований, выполненных до настоящего времени, в особенности тех, которые были выполнены автором самим, он дает сводку форм перигляциальных отложений Северного Среднегорья Венгрии. При этом он показывает, что степень развития и типы перигляциальных форм определяются положением горного массива, условиями его высоты над уровнем моря и слагающими его горными породами. На южных склонах, обращенных в сторону Большой Венгерской Низменности, раздробление коренных пород, а также их снос происходили более интенсивно и гораздо быстрее, чем на северных склонах. Этот факт привел к дальнейшей выраженности резкой асимметрии горного массива. Северное Среднегорье сложено в основном разными типами вулканических пород и подчиненными известняками, которые в свою очередь окружаются зоной третичных отложений, представленных более рыхлыми породами. Все эти породы реагируют на влияние морозов по-разному и прежде всего в разной степени. Рассматриваемое горное сооружение отличается преобладанием денудационных поверхностей разных возрастов и высот, для которых характерны различные по типу и величине перигляциальные формы. В настоящей работе продемонстрируется разнообразие перигляциальных форм разных горизонтов. В заключение дается сводная характеристика наиболее типичных перигляциальных явлений и форм. Автор статьи останавливается на факторах, влияющих на формирование каменных морей, на характеристике разных типов последних и на их влиянии на развитие крупных морфологических форм. Показываются роль и типы осыпей, обломочных покровов и потоков обломочного материала. Совсем кратко затрагивается перигляциальное развитие террас, а более детально — развитие конусов выноса в перигляциальных условиях, с особым вниманием на различия между пери- интерглациалами по структуре, размерам и вещественному составу соответствующих отложений. Автор статьи совсем кратко затрагивает вопрос о перигляциальных песчаных формах, а затем более подробно останавливается на характеристике типов лессовых отложений и на их важной морфогенетической роли. Показываются признаки равнинной и наклонной тундры. Наконец, дается описание формировавшихся в перигляциальные периоды пенепленов и деразионных долин, а также основных их типов.

THE ROLE OF VERTEBRATE FAUNAE AND PALAEOLITHIC INDUSTRIES OF HUNGARY IN QUATERNARY STRATIGRAPHY AND CHRONOLOGY

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In Hungary, Quaternary chronology can boast some important traditions. The evolution of these into a modern science was governed besides the great theories of the Ice Age — and perhaps to some extent in their spite — by the peculiar local conditions. The record of the Pleistocene events is based on the succession of classic Upper Pliocene — Lower Pleistocene and Upper Quaternary mammalian faunae and on abundant prehistoric evidence, confirmed for the last 50,000 years by absolute ages furnished by radiocarbon dating.

Leaving aside the minor units, the stages based on the Hungarian faunal succession subsequent to the Csarnótan are the following: the Villányian and Biharian of the Lowermost and Lower Pleistocene, the latter accompanied by the Buda industry with remains of pithecanthropid Hominids; a subsequent hiatus in the Middle Pleistocene; and a number of levels distinguished on the basis of an ever-increasing volume of evidence including radiocarbon dates and archaeological finds of which the phases of the Subalyuk, of Tata, the Szeleta, Tokod, the Istállóskő and Pilisszántó are the most important.

The demand for the subdivision of the Quaternary formations and for the incorporation of the Quaternary events into a general geochronological sequence — as well as the possibility for satisfying that demand — first arose as a direct consequence of the polyglacialistic approach. However, while in the northern countries the subdivision could be based on the alternation of glaciated and ice-free phases, it was soon recognized that in Hungary there never existed a continental ice sheet similar to the one that invaded the North European countries or of North America and that the glaciations only affected the Hungarian territory indirectly, in the form of periglacial processes (for details see the paper by PÉCSI in this volume).

As a consequence, Hungarian scientists were among the first in Europe to attack systematically the parallelization of our Pleistocene formations on the one hand with the interglacial deposits and with the hiatuses in sedimentation of the glaciated areas on the other, and to establish a corresponding sequence of biological events based on the paleontological material.

I. Historical review

The above-outlined process of scientific evolution was necessarily preceded by certain fundamental discoveries. Among these should be mentioned the recognition of glacial phenomena in the Hungarian territory of

that time (in 1798 and 1861, respectively), the first discovery of the remains of a circumpolar-arctic animal *(Ovibos)* in Hungary (1853), the first recognition of "Diluvial river terraces" (1863), the first traces of Pleistocene Man (1865), and the first description of an interglacial flora — consequently, the first proof of the polyglacial hypothesis in Hungary — in 1890. The first loess stratigraphy prompted by agrogeological studies (1890) and the first malacologic "Diluvial chronology" (1909) also fit into this pattern.

The theoretical basis of the above-mentioned considerations was — beside the increasing volume of research on Ancient Man in Western Europe — A. NEHRING's theory of the alternation of tundra and steppe faunas (1875, 1890), being merely a parallel of F. v. RICHTHOFEN's theory of the origin of loess (1877), and the PENCK—BRÜCKNER theory of fourfold Alpine glaciation (1901—1909).

The trend of research which finally led to the work done today was initiated by a debate, of international resonance, concerning a stone implement of Early Man, found in 1891. The unraveling of the stratigraphic background of the find was undertaken by the Hungarian Geological Institute, that, by this step, assumed in 1906 the task of the systematic paleontological and archeological exploration of the Hungarian Pleistocene cave sites under the direction of geologists and paleontologists, with the final aim of a general Pleistocene stratigraphy. Later on also the Hungarian National Museum and some other institutions joined in the work, although in rather more modest dimensions.

Up to the late thirties, exploration and evaluation proceeded in this same context and it was only after World War II. that the Hungarian National Museum gradually assumed control of the archeological facet of the work.

In the course of the above-outlined activity a rich Vertebrate and Paleolithic implement material was collected and evaluated from the Upper Pleistocene localities, most of which were sited in caves. The paleoanthropological material was incomparably scantier.

The disclosure of the late Pliocene to early Pleistocene karstic localities and the paleontological study of their Vertebrate, mainly micromammalian material, considered classic since the middle of the last century (Villány Mountains, Bihar Mountains) progressed at a similar rate, except for some interruptions of various length.

The results of this stage of research may be summed up as follows:

1. By the analysis of a fairly large number of "cave-bear" and "rodent" faunae a very detailed image of the mammal bird, and very scanty herpetological material of most of the Hungarian upper Pleistocene was presented (KORMOS 1911, KORMOS—LAMBRECHT 1914, KADIĆ 1916, KORMOS—LAMBRECHT 1916, BARTUCZ et al. 1940). The attempts at the classification of the chronological implications of the fossil life thus studied met with

considerably less success; after some unsuccessful initial effort to fit the finds into the NEHRING chronology as modified from the point of view of the four-glacial Alpine system, most of the workers completely rejected the assumption of several glaciations and entrenched themselves in rigid monoglacialism (KORMOS—LAMBRECHT 1916, ÉHIK 1921, KORMOS 1925, 1937a, MOTTL *in* BARTUCZ et al. 1940). Their notions were seemingly confirmed by the fortuitous fact that the excavations of the years 1910 to 1916 yielded exclusively a paleontological material that invited, as it were, the reconstruction of a single preglacial-glacial-postglacial faunal wave. Exploration between the two world wars "completed" this wave with a "last" interglacial fauna (KORMOS 1925) and with a multitude of lowermost and lower Pleistocene faunae (KORMOS 1937a) which seemingly constituted, together with the earlier finds,an uninterrupted preglacial-glacial-postglacial series in the minds of the above-mentioned workers, and to some extent — although this was not laid down in print — in the minds of most of us.

2. One of the richest — if not in numbers, at least in the variety of types and in the implications of the material — middle and upper Palaeolithic sites of Europe has been conscientiously disclosed, and described from Hungary and incorporated into the system of the Western European Palaeolithic. The levels of the complex were after slight differences of opinion and with some divergences, identified with the Mousterian, Aurignacian, Solutrean and Magdalenian (KADIĆ 1934, HILLEBRAND 1935). No misgivings as to the validity of the Western European system in the Carpathian Basin were voiced as yet.

3. As a result of T. KORMOS' activity the enormously rich lower Pleistocene microvertebrate (mainly micromammalian) faunas of the karstic sites of the Villány and Bihar Mountains, accepted since as classic, became known to the scientific world. It was by this work (summarized in KORMOS 1930, 1937a, 1937b) that KORMOS established a broad faunistic foundation for the subsequent very detailed micromammalogic examination and stratigraphic-chronologic evaluation. Although in determining the chronological position of these faunae it was KORMOS rather than his opponents SCHAUB and STEHLIN who started off on the right track, his rigid monoglacialism made it impossible for posterity to adopt his final conclusions as a basis of further work.

II. Principles

In the two decades following World War II. both Vertebrate paleontology and the study of Palaeolithic Man proceeded towards more sharply outlined chronologic aims.

In Quaternary Vertebrate paleontology the main purpose has become to establish a Pleistocene biostratigraphic standard based on the general

principles of geochronology, much more accurate and especially much more detailed than the pre-existing standards.

Paleoanthropologic research was aimed, instead of attempting to force the finds into the Western European systems — an undertaking doomed to defeat to begin with — at a typological revision and definition of the Paleolithic cultures of Hungary; instead of a self-centered typologic hairsplitting at the laying of the foundations of a comprehensive paleoethnologic analysis.

In order to attain the above-outlined aims it had been necessary to set up certain principles on which subsequent work was based.

1. The basis of every kind of geological subdivision, on which every stratigraphic-chronologic zoning is built, is either a sequence of lithologic events (members, complexes, sedimentary cycles), that is, of lithochronologic units, or a sequence of the successive stages of evolution of life (biostratigraphic units). No other basis is accepted in geology for the establishing of stratigraphic-chronologic units.

2. Since the basis of the establishing of lithostratigraphic units and of lithostratigraphic zoning is necessarily the existence of interruptions in deposition or at least in the homogeneity of the deposit, that is, diastrophism, and since the duration of the interruptions is necessarily unknown, the lithostratigraphic units do not exactly fit the chronostratigraphic ones. The biostratigraphic units constitute, however, at the same time chronostratigraphic units because the evolution of Life is free from diastrophisms — that is, the fact and rate of evolution is discernible on the finds even if they do not constitute an uninterrupted time-series.

3. The basis of the classic geochronologic system is the record of the changes, controlled by structural events, of the Mollusc fauna of Western European — Mediterranean shelf deposits, the first of which had been studied in sufficient detail in the first part of the last century. Subsequently the demand for a stratigraphic-chronologic zoning was extended to a number of formations originated under widely different physical conditions, and intensities of diastrophism, such as terrestrial deposits, uninterrupted or almost uninterrupted mid-basin series, etc. The malacologic standards of the shelves could not possibly be applied to these series, not to mention the uncertainties of an eventual parallelization. As a result the chronology of the more continous marine series was gradually reconstructed in terms of Foraminifers, Ostracods, Conodonts, etc. whereas for the terrestrial deposits independent chronologic-stratigraphic standards were devised on the basis of the evolutionary sequences of higher plants and Vertebrates.

4. Since plants were found to be more sensitive ecologic indicators than animals — excepting perhaps the Molluscs — the phytopaleontological sequences, particularly as completed with the pollen record, are most useful from the faciological point of view. From a chronological viewpoint, however, — par-

ticularly as regards the zoning of Cenozoic deposits — the rapidly changing chronologic successions of the highly mobile, quickly spreading Vertebrate faunae offer the greatest advantages. A particularly favourable aspect of the mammalian faunae is that they give well-defined very sharp stratigraphic boundaries — in fact, the sharpest yet established — and corresponding means of long-distance correlation presented in an Eurasian-North-American relation by the invasion of the *Hipparion* wave from North America and in an Eurasian—African relation by the apperance of the Proboscids in Eurasia. — These faunal waves, set off invariably by the largest-scale geological changes, (transgressions, regressions, etc.) are ideally suited as stratigraphic indicators (KRETZOI 1938, 1941, 1953).

5. The statistical evaluation of the very abundant micromammalian populations derived by microstratigraphic collecting from suitable localities indicates characteristic shifts in the relative abundance of the individual species constituting the fauna, both within a certain faunal wave and within the life span of a certain faunal assemblage, although there is no discernible extraneous (ecologic, etc.) reason for any such change. These changes in population dynamism exhibit the same trends, if not the same percentual shifts, over quite large areas even under relatively important differences in facies. Consequently a stratigraphic-geochronologic value can be attributed to the time series of the dominance shifts of the micromammalian faunas. The shifts themselves represent units of time smaller by one order of magnitude than the hemera, the life span of a species, the smallest unit of classic biostratigraphy. They may be termed *phases of dominance* (KRETZOI 1956, 1957, 1961, 1962, KRETZOI—VÉRTES 1965.) These changes of dominance exhibit no recurrence except where there is a sufficient faciological reason (change of temperature, humidity, etc.).

6. On the basis of the dominance parameters of faunal elements of well-known ecologic demands (that is, of species identifiable with those living to-day, which practically means the upper Pleistocene) and by weighing the temperature indications of the individual species with their relative percentual abundance a severally checked absolute-temperature graph has been obtained for the time interval of the evaluated faunae (KRETZOI 1957, 1961, VÉRTES et al. 1964).

III. The Lower Pleistocene and the Plio-Pleistocene boundary

The fossils preserved in the non-marine deposits of the Hungarian territory lend themselves to the establishing of an almost uninterrupted stratigraphic relative-chronologic sequence of the period ranging from the Early Pliocene to our days. The two interruptions of the sequence, hinted at

above, occur between the so-called *Hipparion* faunae and the Upper Pliocene, and between the Lower and Upper Pleistocene, respectively. It is to be hoped that the latter gap will be eliminated by the studies, now in progress, of F. HELLER (Erlangen) and D. JÁNOSSY (Budapest).

The characteristic Central and East European *Hipparion* faunae dominated by *Hipparion*, *Chilotherium* and Cervids come to an end with steppe faunae of *Hipparion-Gazella* dominance. The next faunal wave arrived after a practically world-wide gap in sedimentation as well as in faunal evolution with the long-known Roussillon faunae (DEPÉRET 1890—1897), the Montpellier fauna (GERVAIS 1859), and the lately discovered Ivanovce fauna (FEJFAR 1961). This Ruscinian (KRETZOI 1962, KRETZOI—VÉRTES 1965) based on the stratotype presented by the local faunae of Roussillon very sharply different from the preceding Pannonian (lower and middle Pliocene) faunae. None of the elements of these latter had passed over unchanged to the Ruscinian and even common phyla are rather few in number *(Cricetus*, *Apodemus*, *Hystrix*, Agriotheriids, etc.) Europe was populated at that time by new assemblages whose remarkable majority was of a sub-Himalayan-Oriental origin *(Dolichopitecus*, new Murids, the appearance of true Ursids, *Viverra*-species, *Rusa*-type deer, true Bovids) with some Central Asian—North American elements *(Trilophomys*, true Canids, *Ruscinalopex)*. These faunae indicate, as opposed to the young *Hipparion* assemblages, a gradual expansion of the forest in the area.

A faunal type directly subsequent to the Ruscinian but definitely different is the assemblage named Csarnótan after the first, rich locality where it had been discovered (KRETZOI 1959, 1962). It is characterized in the first place by a sudden wave of Arvicolids arriving from Central Asia (North America?), besides the still important Circetids and Murids. The infiltration of Oriental elements goes on, although in reduced number, with new Soricids, Petauristids, Glirids and Ailurids. It is, however, by no means impossible that these elements immigrated with the preceding, Ruscinian fauna — although they were not yet found in that level.

The Csarnótan as well as the Ruscinian shows a further expansion of the forest elements. The large-mammal fauna is not satisfactorily known yet. Consequently, it cannot be decided yet whether some South Asian Bovids and particularly the true Elephantids *(Protelephas*, *Archidiskodon)* arrived together with the rest of the oriental elements in this phase or only in the subsequent Villányian, in which all the new arrivals are of pronouncedly North American origin.

In the East European facies of more marked grass-steppe affinities a Csarnótan type fauna was found to crop up in Polish localities (Węże — articles mostly of KOWALSKI and SULIMSKI). Further south the faunae of the so-called Odessan "catacombs" belong to this group.

The Csarnótan is separated by a sharp ecologic change from the subsequent Villányian (KRETZOI 1941, 1956, 1961). The abrupt change indicates a profound shift of climatic zonality. Whereas the Csarnótan indicates a sub-Himalayan monsoon-forest type milieu, the Villányian, in practically the same locality, exhibits a continental grassland character. Accordingly, in the stratotype area of both stages, the Villány Mountains, the faunae of the Villányian practically lack the characteristic forest micromammals (Sciurines, Glirids, Petauristids); also the predominant Murids of the Csarnótan are almost totally absent, being superseded by the Arvicolids. The rodent fauna contains besides these latter almost exclusively Cricetids, Marmotines and finally Spalacids, indifferent in this respect. However, the micromammal assemblage of the Villányian differs from that of the Csarnótan also in the disappearance or modification of several elements and in the arrival of new elements, especially the more modern types of Arvicolids and Soricids.

A fact of considerable importance for the separation of the Pliocene from the Pleistocene is the joint occurrence of a rich large-mammal fauna and a chronologically well-defined micromammal assemblage in one of the Villányian faunas (that of Kisláng) suited to further subdivision (KRETZOI 1954). It is this fact that opens up the possibility to more sharply define the Pliocene-Pleistocene boundary accepted by the London session of the Geological Congress in 1948 (OAKLEY 1950).

The Villányian wave can be divided into two larger phases, those of Beremend and of Valdarno (KRETZOI 1956). The former is characterized by the primitive Csarnótan Soricids, *Dolomys* and the early species of *Mimomys* featuring cementless molars, the latter by the appearance of a number of modern elements (*Sorex*, *Crocidura*, *Myodes* = *Clethrionomys*), *Kislángia*, *Lagurodon*, *Allophaiomys*, etc.) as well as by the expansion of the evolved species of *Mimomys*. In the large-mammal assemblage of Kisláng, where besides the two Mastodontids (*Anancus* and *Mammuthus*) a variety of *Archidiskodon meridionalis* of rather primitive dentition is the dominant Proboscid, there occur masses of the two "Zebroid" types of horse, the small *Allohippus stenonis* (COCCHI) and the big *Macrohippus silvarum* KRETZOI 1938 (= *Equus bressanus*, VIRET 1954) besides the scarce, disappearing *Hipparion*. The picture is completed by *Leptobos*, *Euctenoceros* as well as by the usual "Valdarno forms", besides a Camelid and a Struthionid (KRETZOI 1954). The large mammals are accompanied by a typically upper Villányian (Valdarno) small-mammal assemblage.

Now if the Plio-Pleistocene boundary is set in accordance with the proposal of the London Congress at the base of the Valdarno fauna, this means the cutting in two of a single phase of faunal evolution. This could perhaps be explained on the grounds of the imperfect coincidence of the biologic and geologic interfaces, but the abrupt change from the sub-Himalayan

forest phase to the continental dry steppe phase, an event of considerable geological importance, happens to coincide exactly with the limit of the two faunal waves. This is a strong argument in favour of setting the Plio-Pleistocene limit between the Villányian and Csarnótan complexes, where the disappearance of the Murids, Glirids and Petauristids and the decisive breakthrough of the Arvicolids constitutes a strong geological turning-point, rather than to put it between the phases of Beremend and Valdarno (KRETZOI 1962).

In the faunal composition of the Villányian even the youngest levels of the faunistic wave are free from any glacial indication, except for the single genus *Lemmus* (HELLER 1963). The Northern elements first appear in the Central European region with the next faunal wave. If one supposes nevertheless a certain deterioration of the climate to have taken place in the late Villányian, it is because the uppermost Villányian fauna of the Villány-5 locality, overlying the terra rossa of the classic Valdarno-type small-mammal fauna at Villány, occurs in a yellowish brown loessy loam rather than in the cherry-red terra rossa, a fact that undoubtedly indicates some change in climate (KRETZOI 1956). This same change might be proved by the *meridionalis*-bearing and *Mastodon*-less gravels of the St. Prest "stage" overlying the *Mastodon*- and *meridionalis*-bearing layers of the French "Villafrancan" — but, then, this shift may just imply a dry milieu as opposed to the swamp-forest type *Mastodon* biotope.

The richest locality of the next wave, the Biharian (KRETZOI 1938, 1941) also occurs in the Villány Mountains. It is represented by a series of deposits of considerable thickness that lends itself excellently to a further refining of the subdivision. The stratigraphic-evolutionary value of the faunal wave is enhanced by the fact that besides the karstic facies of the Villány Mountains also the waterside and mountainous-forest-type facies (KORMOS 1930, KRETZOI 1938, 1941a, 1941b, 1941c, JÁNOSSY 1956, 1962b, 1963) of the Biharian are known from within the Carpathian Basin.

The Biharian wave is plainly distinguishable from the Villányian. In earlier literature it was between the two that the Plio-Peistocene boundary had been drawn (*"Mastodon"* gravels as opposed to *"meridionalis"* gravels), and some, as e.g. the main representives of the Basel school (STEHLIN, SCHAUB) still adhere to this view.

Between the Biharian and Villányian wave the differences are sharper both as regards the large and small mammals than between any two of the preceding stages. Of the typical Villányian elements most of the Tertiary forms are seen to disappear, as e.g. all extinct Soricids with the exception of *Beremendia* and *Drepanosorex*, *Prospalax* of the rodents, all primitive species of *Mimomys*, the Nyctereutines of the Carnivores, all extinct Mustelids (*Pannonictis*, *Xenictis*, *Baranogale*), the *Megantereon*, etc. both Mastodontids

(Anancus, Mammuthus), the tapirs, the last *Hipparions*, the *Rusa*-type deer, *Euctenoceros*, the antelopes and *Leptobos*.

On the other hand there appear all the genera of our present fauna, not yet present in the Villányian, as well as some other that receded since or became extinct. To these belong the Cuonines, *Gulo*, *Crocotta*, the lemmings, *Rangifer*, the Ovibovines — essentially the first true Arctic elements in the Central European region — and the insectivorous and rodent elements of our present fauna, absent till then. Also the genera extending from the Villányian into the Biharian are represented by distinct species.

In the possession of the extremely rich material of the Villány Mountains localities it became possible to order the faunal successions of the Biharian into a continual history of faunal evolution, representing the actual dynamism of the process rather than generalizations of a few specific faunas separated by long intervals of time. By determining the characteristic phases of this dynamic process it became possible to subdivide the Biharian into several dominance phases (KRETZOI 1956, 1961, 1962, KRETZOI—VÉRTES 1965), defined by the shifts of dominance recorded in a spectrum (KRETZOI, 1961).

The six phases of the Biharian outline among them two well-defined climatic oscillations, of which the first starts out with the warm-climate fauna of the lower vivid red clays and ends with the relatively cold-climate fauna of the upper increasingly pale clayey layers. The upper oscillation first presents a relatively warm aspect, only to terminate with a loess fauna substantially colder than the terminal phase of the foregoing oscillation (KRETZOI—VÉRTES 1965). Also the faunal assemblages evince differences that justify the division of the Biharian into a lower and an upper unit, although the six phases mentioned above cannot yet be discerned in the large-mammal material. To accomplish the zoning also of the latter, the parallelization of the individual phases of the Elster glacial with the corresponding phases of the Biharian will have to be carried out (KRETZOI 1965).

It is in the course of the Biharian wave that a toolmaking Hominid, *("Pithecanthropus"* sp.) living in settlements provided with hearths, first appeared in Europe (Vértesszöllős) and settled there in the phase of the upper Biharian (KRETZOI—VÉRTES 1965). His settlement furnished a restricted but suggestive palaeoanthropologic material.

This Buda-Industry exhibits remarkable affinities with the South and Southeast Asian cultures (Choukoutienian, Sohan, Anyatian, etc.) as well as with the South and East African ones (advanced Kafuan, Oldowan). It further seems to be related also to the somewhat younger Clactonian of England. As the pebble industry of the Vértesszöllős settlement, the one that furnished the most abundant data, does not differ substantially in age from the Asian localities, nor from the West European ones, this fact raises once more the problem whether the astoundingly old age (HOWELL 1962) obtained by

potassium-argon dating for Olduvai in Africa is acceptable. It is highly problematic whether this primitive pebble culture could persist in essentially the same morphologic habit throughout more than one million years.

IV. The subdivision of the Upper Pleistocene and of the Holocene

A characteristic feature of the state of affairs concerning the problem in point is that the discussions centered on the subdivision of the Upper Pleistocene are more informative than the hypotheses reconstructing Ice Age history themselves. The first deduction is that although it was correct from the geological point of view to call the oldest stadial of the "Würm" glaciation the "first", and to increase the numbers upward to the youngest "third" or "fourth", the recognition of further stadials necessitated the inclusion of further symbols (*a*, *b*, etc.) or new names into the pattern. It would have been more appropriate to designate these phases by the name of the first-recognized or most representative occurrance.

The richer the data from a geological period not too far removed in time, the intenser the controversy. This is but increasing with the exploration of new regions and the faciologic differences observed within the same. It appears that the hardest thing in Quaternary research is just to stick to the observed facts and to draw conclusions avoiding the pitfalls of pre-existing patterns and preconceived notions.

The most frequently employed patterns were the valuable conceptions of PENCK, BRÜCKNER, SOERGEL, later on of MILANKOVIĆ and others, that contributed substantially to the advancement of their respective disciplines. The interpretations, however, of these conceptions as adapted to other disciplines were not long-lived. Since 1950 the new backbone of our attempts in zoning is radiocarbon dating. Although mistrustful in the beginning, most of the workers lean ever more confidently on radiocarbon dates, and the increasing number of results seems to produce some kind of justification for this confidence. The results may be distorted by contamination and it is very likely that e.g. 30,000 radiocarbon years do not exactly equal 30,000 years on the calendar, but the irrefutably good internal coherence of the data seems to suggest that at least 30,000 radiocarbon years equal 30,000 radiocarbon years almost everywhere.

The chronology based on the radiocarbon dates has revealed that the evidence available for the construction of a "Würm" chronology of general or even only European validity is very scanty indeed. Another source of the dissension is the highly varied interpretation of the terms interglacial, interstadial, etc. We did not take pains to set up exact limits for the temperature, raininess, faunistical composition or lithologic character of the terms in

question. The aspect of a given Pleistocene climatic phase has not been evaluated in its dependence on latitude. All the above-enumerated problems have led the present authors to give in the following the absolute ages obtained up to now for the Hungarian Upper Pleistocene together with the correlated paleontological and archaeological observations, without taking sides in the general discussion, and to employ, at least for the time being, their own nomenclature. These provisional terms can eventually, the development of the general Quaternary chronology permitting, be substituted by the definite general ones.

Coming back to the division of the Upper Pleistocene, the end of the Biharian wave marks for the time being a break in the continuity of the faunistic-dynamic record. In the present paper we shall skip this gap covering the middle Pleistocene; the promising attempts at its bridging over are reported by D. JÁNOSSY in a separate paper in this volume. We shall proceed instead to the discussion of the Upper Pleistocene. For the Upper Pleistocene waves — just as for the precedent one — no new term was coined. We have accepted the names Oldenburgian and Utrechtian given by LÜTTIG originating in a geohistorical viewpoint very similar to our own.

Let us begin our treatment of the Utrechtian with the remark that the period subsequent to the Biharian wave constitutes essentially a single faunal wave: the fauna that substituted the vanished elements of the Biharian wave only differs from that of to-day in such accessory colours as the large Mammals of Tertiary origin, adapted to the Pleistocene climate (the mammoth, the rhinoceroses), and some occassinonally present Arctic forms (lemmings, polar fox, musk ox, white ptarmigan). We shall not enter here into a detailed analysis of the parallelisms; let us remark only that the differentiation of the Oldenburgian from the Utrechtian faunae cannot be performed with any degree of certitude except on a material gained by up-to-date microstratigraphic collecting techniques. This is why the discussions concerning the point (e.g. that about V. GROMOV's so-called Rissian and Würmian faunae) were futile. It is for this same reason that the solving of the problems by means of the "index species" of faunae synthetized in an armchair out of sporadic finds cannot possibly lead anywhere (K. D. ADAM 1964).

A task that can, however, be tackled with a fair chance of success is a review of the faunal succession practically uninterrupted from the warm-climate phase that can in all probability be identified with the last interglacial (the "Eem") up to the present and its correlation with the relative chronology based on the archaeological material and with the absolute chronology furnished by the radiocarbon method.

For the period in question we have at our disposal a zoning based on the one hand on the large mammals (KRETZOI 1953, JÁNOSSY 1963—64), and on the other hand on the population dynamism of the dominant micro-

mammals, the voles (KRETZOI 1956, 1957, 1961, 1962, KRETZOI—VÉRTES 1965). On the basis of the latter even an absolute-temperature graph of the mean July temperatures as indicated by the faunal assemblages has been constructed (KRETZOI 1957, 1961 etc.).

The examination of the large-mammal fauna has first shown up five phases of Upper Pleistocene faunal evolution (KRETZOI 1953). The necessity of adding a sixth was proved by JÁNOSSY (1963—64). The correlation of archeological, faunistic and speleolithologic evidence with one another and partly also with the MILANKOVIĆ—BACSÁK pattern of climatic rhythms has resulted in the establishing of a seventeen-term succession (VÉRTES 1959).

Taking into consideration the Palaeolithic cultures, the stratigraphic records of the caves (VÉRTES 1965a) as well as the lately obtained radiocarbon dates, we have set up the following Upper Pleistocene chronology:

1. *Süttő phase* (KRETZOI 1953). The phase is characterized by the lack of Arctic elements and the presence of forms of Mediterranean haunts *(Testudo;* large Carnivores: *Crocotta*, *Leo*. The forms of these latter are smaller than their "*spelaeus*" varieties). There is no irrefutably associated archaeological material.

2. *Varbó phase*. (JÁNOSSY 1964). The Mediterranean elements have disappeared, the fauna is of a mixed forest-steppe type. Last appearance of *Hystrix*, *Allactaga*, *Allocricetus;* the assemblage is characterized by *Asinus hydruntinus* and the first artic elements. The cave bear is still sporadic. The flora contains *Celtis* as its most eminent form. This combination agrees with the general experience that after the "Eem" there is a stage where *Celtis* disappears, the last *Celtis*-bearing layers are directly overlain by deposits containing cave-bear remains. It is from this point that can be counted the beginning of the second part of the Utrechtian stage, that is, the German "Altwürm" as defined with the exclusion of the Warthe in the original sense. It is, however, by no means impossible that the limit thus established intersects the glacial oscillation supposed between the Amersfoort and Brørup interstadials rather than the one between the Eem and the Altwürm (WOLDSTEDT 1962).

The appearance in the cave deposits of the cave bear, a typically Upper Pleistocene fossil, is a milestone of faunal evolution that can usefully serve as a starting point of further considerations.

The alternation of *Celtis* and *Ursus spelaeus* can most readily be observed in the LAMBRECHT cave at Varbó. This is the locality from where JÁNOSSY described the Varbó phase on the basis of more than 100 taxa of which more than 70 species were fossil mammals. The site was inhabited by Pleistocene man; the scarce, roughly worked implements indicate a Mousterian culture in the broader sense of the term (VÉRTES 1965a).

3. *Subalyuk phase.* (KRETZOI 1953). Together with the subsequent phase this one marks the advance of the arctic-subarctic steppe elements and the withdrawal of the warm-climate forest assemblage. In the cave sequences the cave bear gradually becomes the dominant element. *Asinus* and *Cuon* are fairly frequent, as is *Lagurus* among the smaller mammals. The stratotype of this phase is the lower level of the Subalyuk cave. It yielded a fine Mousterian industry, exhibiting a close affinity to the "moustérien typique" group of Western Europe (BORDES 1950). We have no radiocarbon indication of the age of this level. Above it there follow strata — presumably with an unconformity — containing besides the cave bear further cold-climate indicators, specifically, the members of the Upper Pleistocene forest fauna of the Bükk Mountains as well as an industry resembling the French Charentian and the bones of Neanderthal Man. Their absolute age is implied by their tentatively established contemporaneity with the Tata find, to be described below.

4. *Tata phase* (nov.). The study of the rich material furnished by the Tata site has recently been published in a monograph (VÉRTES et al. 1964). The cultural layer of the "travertine site" overlies a layer of travertine containing *Celtis* and *Mastus bielzi*, that is, elements of interglacial character. The layers of calcareous tufa intercalated between the travertine and the layer of the site exhibit no trace of climatic change. The Middle Paleolithic industry was found in a loess-like layer indicating a brief spell of dust deposition. The mean July temperature of the deposition is indicated by the Mammal and Gastropod fauna as well as by the charcoal fragments consisting of deciduous wood to have been about 18 to 19 degrees centigrade. The industry is a special one, belonging to the Mousterian in the broader sense (Tata industry). The absolute age (GRO 2538) is 50,000 $\pm$ 2500 years, approximately the same as Brørup interstadial. The inclusions of the tufa horizons overlying the occupational level indicate an interstadial climate for the lower layers. By the time of deposition of the upper layers it changed into one of stadial affinities.

In Hungary the time span of the Mousterian culture and of its derivative, the Szeleta culture is represented by several localities of abundant fauna and simple and decisive stratigraphic record. For this reason it was our aim to obtain radiocarbon dates for the established climatic changes of this period. The examination of five of our samples in the Geochron Laboratory of Chicago has been made possible by a grant from the WRNNER-GREN Foundation.

5. *Szeleta phase.* The implements of the early Szeletian industry occur in the lower layers of the Szeleta cave. The age of the light brown layer (GXO 197, Geochron. Report, 25. jan. 1965) is $>$ 41,700 years within a limit of error of 2 σ. Both the lithologic features and the fauna of the layer indicate wet, cool forest conditions. The absolute age of this layer can be usefully

confronted with that of a Slovakian locality within the same climatic area: the data of the layer determined as Szeletian of Čertova pec is (GfN—2438) 38,400 + 2800—2100 years (VOGEL—WATERBOLK 1964, BÁRTA 1961). Geographically not much farther away, in layer No. 6. of Nietroperzowa in Poland further finds corresponding to the Szeletian have been described with an accompanying material of interstadial implications (CHMIELEWSKI 1961). The industry differs from our Szeletian, but a leaf point from that locality deposited in our collection (PONGRÁCZ 1922, 1925) as well as the illustrations in the above-cited paper by CHMIELEWSKI suggest that it belongs to the same morphological level. The absolute age of the Polish layer (GrN 2181) is 38,500 ± 1240 years (VOGEL—WATERBOLK 1964).

The Geochron date fixes also the age of the lower, Aurignacian I industry of the Istállóskő cave on the basis of the repeatedly proved contemporaneity of the two archaeological horizons (VÉRTES 1955b, 1961a).

The absolute age of the upper layer of the Büdöspest cave (GXO 198, 11 Feb 1965), not less than 37,000 years with a probable error of 2σ seems too young.

The archaeological finds of the two cultural horizons — situated at a vertical distance of 2 to 3 metres — of the Büdöspest cave constitute a link between the Mousterian industry of the Subalyuk cave and the early Szeletian culture (VÉRTES 1962—63). We have no adequate reason to suppose that groups of men who lived in the proximity of each other for several thousand years and moved back and forth in a relatively restricted area necessarily went through the same stages of evolution simultaneously. On the contrary, it would be more puzzling to find at the time when a group of the Mousterian men were developing Szeletian culture in the stricter sense — or even after — no other group of men adhering to the traditional Mousterian culture and set of implements. It is on the basis of the above considerations that we assume the younger age of the upper cultural horizon of the Büdöspest to be younger than the lower layers of the Szeleta cave, but the few radiocarbon dates at our disposal do not warrant a definite decision. Therefore the problem of a definitive dating is left open for the time being.

6. *Tokod phase* (nov.). It was the find of Tokod—Nagyberek that seemed best suited to determine the age of that cold oscillation of which nothing is known but that it is considerably above the Tata culture (50,000 C^{14} years). At Tokod, JÁNOSSY has found, in a loessy layer intercalated between beds of travertine, some lemmings together with the remains of *Asinus*, *Bison*, etc. (JÁNOSSY 1965.) The presence of Man is indicated by some quartzite hammerstones, choppers and of charcoal. Up to now this is the only locality in Hungary that yielded lemmings together with a large-mammal fauna containing *Asinus hydruntinus*, an "Altwürm" index fossil, and dominated by *Bison*. That is why it can be identified with the cold maximum between the "Alt-

würm" and the "Mittelwürm". Its age (GXO 196, 11. Feb. 1965) is 36,200 years with a possible error of 2 σ. The radiocarbon ages have been determined in the case of the Tokod finds as well as in those of the Szeleta and Büdöspest localities on collagen extracted from bones. Collagen seems to be the most suitable material as even in older Pleistocene bones it was found in its original molecular structure (I. LENGYEL 1964). Thus the result is not likely to be impaired by subsequent atomic exchange or contamination. Even considering this circumstance, however, we think that the radiocarbon age of the lemming layer of Tokod is too young — at least in the light of our hypothesis — but we must confess that the radiocarbon result is confirmed e.g. by the *Microtus gregalis* horizon of the lower layer of the Istállóskő cave and also by the stratigraphic record of the Peskő cave.

To give a general faunistic characterization of these phases, merging more or less gradually into each other, we may state that, at the Subalyuk and Tata levels, cave bear was still scarce; at the Szeleta level it already became the dominant species, whereas the presence of the collared lemming at the Tokod level indicates the extension of the tundra zone down to our latitudes.

7. *Istállóskő phase* (nov.). The upper layer of the Istállóskő cave, marked by an Aurignacian II culture, is rather sharply distinguished from the foregoing phase also faunistically, by the disappearance of the arctic and definitely steppe-type elements. The fauna indicates once more a milder phase of forest character, in which *Alces* and the beaver rose to considerable abundance while in the micromammalian fauna *Arvicola* was remarkably frequent. The age of this layer is set at 30,900 $\pm$ 600 radiocarbon years by the result GRO—1935 (VOGEL—WATERBOLK 1963). It was found to be overlain by a loessy layer still containing Aurignacian implements. Above this latter there is a glacial layer, containing congelifractate detritus, the fauna of which markedly differs from those of the foregoing layers. It is impossible to tell as yet whether these two upper layers are older or — what is more probable — younger than the next locality to be described.

On Henye-Hill at Bodrogkeresztúr a loessy layer containing an occupation site belonging archaeologically to the older stage of the Eastern Gravettian has lately been disclosed. The fauna is dominated by the elk, which in this case has a significance largely as a biotope indicator; the horse, red deer, mammoth, etc. are also abundant. The vegetation is dominated by charcoal from the *Larix-Picea* group (as opposed to the *Pinus cembra* of the uppermost layers of the Istállóskő). All these circumstances reflect interstadial conditions, and according to an examination by L. MOLDVAY the occupation level is less loamy than the overlying deposit (VÉRTES 1965b). The age of the culture layer (GXO 195, 30 Nov. 1964) is 28,700 $\pm$ 3000 years. This date compares with the radiocarbon ages of two nearby Eastern Gravettian sites as follows: Nemsová (GrN—2470): 28,570 $\pm$ 1300 years (VOGEL—WATER-

BOLK 1964), where the finds occurred in a deposit of interstadial implications, and Nitra-Čermán (GrN 2449): 23,000 ± 330 years, where the conditions do not indicate an interstadial any more (VOGEL—WATERBOLK 1964). Confronting all the available evidence we perceive that the long interstadial phase came to an end about 28,000 — 27,000 years ago in our region.

Between the phase of Istállóskő and the subsequent phase there is a discontinuity both from the faunistic and the archaeologic point of view. This is apparent also in the faunal spectra of the Arvicolids. There is no indication, however, of an interruption in the continental-glacial climate up to the time marked by the upper occupation site of Arka (see below). It is within this more or less homogeneous period that we find the

8. *Pilisszántó phase* (KRETZOI 1953). It is characterized by the disappearance of the cave bear and the other large Carnivores and by the dominance of the reindeer. The recession of the forest elements is emphasized by the growing abundance of the arctic voles, mainly of the collared lemming, indicating a milieu consisting of a mosaic of subarctic steppe, taiga and tundra. By that time the region was already densely inhabited on a Palaeolithic scale; Eastern Gravettian groups roamed about in the loess while the caves were occupied by the hunters of the Pilisszántó culture.

On the basis of the examination of both the rock-shelter of Pilisszántó and the Jankovich cave (KRETZOI 1957, VÉRTES 1959) we have reached the conclusion that the maximum of the last stadial had occured before our four Gravettian dates to be enumerated below, that is, earlier than 19,000 years ago. For that time, however, we have no radiocarbon date as yet. The cold peak is indicated by the yellowish- and greenish-grey layer of the Pilisszántó rock-shelter and by the sample No. 10 of the 1955 excavation in the Jankovich cave (KRETZOI 1957, Fig. 10).

9. *Arka phase* (nov.). The phase is established on archaeologic as well as lithologic evidence. In its fauna the reindeer is still the dominant large mammal. The dominance graph of the Arvicolids shows it to be marked by a slow warming up of the climate. Four radiocarbon dates referring to this phase are associated with Eastern Gravettian industries, reindeer-bearing faunae and *Pinus*-bearing plant assemblages:

Ságvár, lower layer (GrN—1783):	18,900 ± 100*
Ságvár, upper layer (GrN—1959):	17,760 ± 150*
Arka, lower layer (GrN—4038):	17,050 ± 350*
Arka, upper layer (GrN—4218):	13,230 ± 85**

10. *Palánk phase* (nov.). The upper Pleistocene elements are still present but their abundances are on the decrease. They are accompanied by elements

* (VOGEL-WATERBOLK 1964)
** (Private communication by J. C. VOGEL in a letter dated 27 July 1964.)

living today (deer, beaver); in the vegetation deciduous forms *(Populus)* are dominant. Terminated by a brief cold oscillation, the Palánk phase as a whole is marked by the horizon of fossil soil above the upper occupation layer of Arka whose counterparts are found also in some of our caves (Sample No. 5. of the Jankovich cave). The situation could be established most clearly in the Epipalaeolithic occupation site of Szekszárd—Palánk (VÉRTES et al. 1962) where this horizon has been successfully postdated by a thin loess layer corresponding to the Younger Dryas of Western Europe. Its age (H 408 C + + B 1371) is 10,350 ± 500 years according to a private communication by K. O. MÜNNICH (1962).

11. *Bajót phase* (nov.). The characteristic Upper Pleistocene species are completely gone but the climate, as indicated by the few subarctic elements that remained [*Ochotona*, *Phodopus* (= *Cricetiscus) sungorus*, etc.] is of a grassland type, cooler than the present one. From the archaeological point of view the level is characterized by Mesolithic or late Epipalaeolithic finds. The phase may be identified with the early Boreal.

12. *Körös phase* (nov.). The faunal assemblage indicates the warm peak of the Holocene with predominantly steppe-type elements. It coincides with the Quercetum mixtum horizon of palynology. The fauna is dominated by *Cricetus*, *Microtus arvalis*, *Sicista*, etc. (KRETZOI 1957).

13. *Bükk phase* (nov.). Cooler than the preceding one, this phase exhibits forest-types affinities resulting in the withdrawal of most of the steppe elements that stayed on since the postglacial, and in their being replaced by forest elements *(Clethrionomys)*. The phase coincides with the birch phase of palynology. Archaeologically it can be parallelized with the Bükkian culture of the Neolithic and with the younger phase of the Tisza-culture.

14. *Alföld-* (Great Plains-) *phase*. (nov.). With the gradual expansion of the cultivated steppe the steppe elements expand once more; the forest species withdraw; and the conquest of the region by Man is marked by the gradual extinction of big game (KRETZOI 1964). This is the phase we are living in today.

Summing up the above observations we may state the following:

The second part of the Upper Pleistocene (or of the Utrechtian stage) is inaugurated by a rainy phase warmer than the present climate. The subsequent gradual cooling is sharpened by the more abrupt cold peak of the Tokod phase. Preceding this latter, four phases or more of less distinct faunistic and lithologic record could be established: firstly, the Varbó phase, secondly, the Subalyuk phase with some interglacial elements still present, but with the cave bear in ascendancy; thirdly, the Tata phase, a late stage of the Subalyuk phase with *Lagurus* still represented, corresponding either to the Bølling interstadial or to the cold oscillation linking the Bølling with the Amersfoort, practically unobserved as yet in this country. The Tata phase is succeeded,

presumably without any substantial change in temperature, by the fourth Szeleta phase represented by the lower layers of the Szeleta and Istállóskő caves. The subsequent Tokod phase containing markedly cold-climate forms, comprises in the Bükk Mountains the top of the lower layer with *Microtus gregalis* and *Pinus cembra* of the Istállóskő cave and to some extent also the layer containing the congelifractate detritus in the Büdöspest. The climate after the Tokod phase, that is, between about 37,000 and 28,000 years, was cool and humid, presumably with several minor cooler and warmer oscillations. We know of no loess deposit of any importance from this phase. The interval beginning with the warming up and terminated by the cooling of the climate is called the Istállóskő phase.

From 28,000 to at least 13,000 the climate was a uniformly glacial-continental one. The cold peak at the end of its first half is called the Pilisszántó phase, its second half is termed the Arka phase. The latter is succeeded by the Palánk phase beginning with a moderate spell (corresponding to the Alleröd) and ending with a brief time of dust deposition. This phase is the terminal incident of the Pleistocene. We have listed some of the characteristic post-glacial phases, the Körös, Bükk and Alföld, with their successive dates.

The above results tend to confirm our standpoint that almost all prehistoric cultures known from Hungary are crammed up in the brief interval between about 45,000 and 28,000 radiocarbon years ago (VÉRTES 1961b). The representants of the Mousterian culture were still in existence when the Szeletian was developed in this country to be shorthly followed by the Aurignacian and even — as witness the finds of the Istállóskő and Szeleta caves — by the first wave of the Eastern Gravettian. In the subsequent period of about 15,000 years the Eastern Gravettians were supreme in the area, at least if one counts as Eastern Gravettian also the supposed variants (culture of Pilisszántó); it was those that developed after a long evolution the Mesolithic in our region.

The above picture of the chronologic-ecologic-archaeologic picture of the Hungarian Quaternary is far from being complete. As against many other subdivisions, some of them much more attractive, it possesses the advantage of being based on facts rather than hypotheses. In the absence of adequate data, some problems have been left open, in the conviction that a question mark indicating the lack of sufficient evidence is preferable to the displaying of dubious knowledge.

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REFERENCES

ADAM, K. D.: Stuttg. Beitr. z. Naturkunde **132,** 1—12, 1964. — BÁRTA, J.: Acta Archaeol. Carpathica **2,** 1961. — BARTUCZ, L. et al.: Geol. Hung. Ser. Palaeont. **14,** 1—352, 1940. — BORDES, F.: L'Anthropologie **54,** 393—420, 1950. — CHMIELEWSKI, W.: Archaeol. Polon. **4,** 54—63, 1961. — DEPÉRET, CH.: Mém. Soc. Géol. France **3,** 1—198, 1890. — ÉHIK, GY.: Ann. Mus. Nation. Hung. **18,** 89—110, 1921. — FEJFAR, O.: N. Jb. f. Geol. Paläont. Abhandl. **111,** 257—273, **112,** 48—82, Monatshefte 267—282, 1961. — GERVAIS, P.: Zoologie et paléontologie françaises. Paris 1—544, 1859. — GROSS, H.: Quartär **14,** 49—68, 1962—63. — GROSS, H.: Eisz. und Gegenwart **15,** 187—198, 1964. — HAUG, É.: Traité de géologie. I—III. Paris 1911. — HELLER, F.: N. Jb. f. Geol. Paläont. Abh. **118,** 1—20, 1963. — HERRMANN, M.—KRETZOI, M.—VÉRTES, L.: Folia Archaeol. **9,** 3—32, 1957. — HILLEBRAND, J.: Archaeol. Hungar. **17,** 1—86, 1936. — HOWELL, F. C.: Current Anthropology **3,** 306—308, 1962. — JÁNOSSY, D.: Ujabb ópleisztocén ősgerinces-lelőhelyek Magyarországon (Budapest-Várhegy, Üröm, Répáshuta). (New finds of early Pleistocene vertebrates in Hungary.) Manuscript. — JÁNOSSY, D.: Állattani Közl. **49,** 63—74, 1962a. — JÁNOSSY, D.: Ann. Mus. Nat. Hungar. **54,** 155—174, 1962b. — JÁNOSSY, D.: Ann. Mus. Nat. Hung. **55,** 109—141, 1963. — JÁNOSSY, D.: Acta Zoologica Acad. Sci. Hung. **9,** 293—331, **10,** 139—195, 1963—64. — JÁNOSSY, D.: A Tokod-Nagyberek-i kőfejtő felsőpleisztocén gerincesfaunája. (Upper Pleistocene vertebrate fauna of the quarry of Tokod-Nagyberek.) Esztergomi Múzeum Évkönyve 1965. (In press) — KADIĆ, O.: M. Áll. Földtani. Intézet Évkönyve **23,** 157—302, 1916. — KADIĆ, O.: M. Áll. Földtani Intézet Évkönyve **30,** 1—147, 1934. — KADIĆ, O.—KORMOS, T.: M. Áll. Földtani Intézet Évkönyve **19,** 117—163, 1911. — KORMOS, T.: Állattani Közlem. **22,** 159—180, 1925. — KORMOS, T.: Állattani Közlem. **27,** 57—62, 1930. — KORMOS, T.: Strand-Festschrift **3,** 287—328, 1937/a. — KORMOS, T.: Magyar Tud. Ak. Mat.-Term. Tud. Értesítője, **56,** 1063—1100, 1937. — KORMOS, T.—LAMBRECHT, K.: Magy. Áll. Földtani Int. Évkönyve **22,** 347—382, 1914. — KORMOS, T.—LAMBRECHT, K.: Mitt. a. d. Jahrb. d. kgl. Ungar. Geol. R.-Anst. **23,** 331—523, 1916. — KRETZOI, M. *in* KADIĆ—KRETZOI: Barlangkutatás **14—15,** 20—40, 1927. — KRETZOI, M.: Ann. Mus. Nat. Hungar. **31,** 88—157, 1938. — KRETZOI, M.: Ann. Mus. Nat. Hung. **34,** 56—82, 1941a. — KRETZOI, M.: Ann. Mus. Nat. Hungar. **34,** 105—139, 1941b. — KRETZOI, M.: Földtani Közlöny **71,** 308—335, 1941c. — KRETZOI, M.: Acta Geologica **2,** 67—76, 1953. — KRETZOI, M.: Magyar Állami Földtani Intézet Évi Jelentése 1953-ról, 239—264, 1954. — KRETZOI, M.: Geol. Hungar. Ser. Paleont. **27,** 1—264, 1956. — KRETZOI, M.: Folia Archaeologica **9,** 16—21, 1957. — KRETZOI, M.: Magyar Tud. Ak. Műsz. Oszt. Közleményei **23,** 365—378, 1959. — KRETZOI, M.: Stratigraphie und Chronologie *(in :* RÓNAI—PÉCSI—KRETZOI, Stand der ungarischen Quartärforschung). Inst. Geol. Prace **34,** 313—330, 1961. — KRETZOI, M.: Magyar Áll. Földtani Intézeti Évi Jelentése 1959-ről, 297—382, 1962. — KRETZOI, M.: Die Wirbeltierfauna des Travertinkomplexes von Tata *(in* VÉRTES 1964, below), 105—126, 1964a. — KRETZOI, M.: A gerinces állatok története (Evolution of Vertebrate Animals). *in :* A természet világa, Gondolat 351—545, 1964b. — KRETZOI, M.: Paläont. Abh. 365—440 1964c. — KRETZOI, M.—VÉRTES, L.: Acta Geologica **8,** 313—317, 1964. — KRETZOI, M.: Physical conditions and chronology of the "loess period" in Hungary as indicated by Vertebrate faunae. 1965. (Manuscript). — KRETZOI, M.—VÉRTES, L.: Curr. Anthrop. **6,** 74—87, 1965. — LENGYEL, I.: Bull. Gr. Internat. Rech. Sci. Stomatol. **7,** 182—206, 1964. — MOTTL, M.: A Magyar Áll. Földt. Int. Évkönyve **36,** 71—125, 1942. — OAKLEY, K. P.: Swanscombe man. Proc. Geol. Assoc. London, **63,** 271—300, 1952. — PONGRÁCZ, S.: Barlangkutatás **10—13,** 59—61, 1925. — VÉRTES, L.: Acta Archaeologica **5,** 239—260, 1955a. — VÉRTES, L.: Acta Archaeologica **5,** 261—278, 1957b. — VÉRTES, L.: Régészeti Füzetek II. **7,** 1—176, 1959. — VÉRTES, L.: Germania **39,** 295—298, 1961a. — VÉRTES, L.: Ber. ü. d. V. Internat. Kongr. f. Vor- u. Frühgesch. Hamburg 1958, 634—838, 1961b. — VÉRTES, L.: Archeol. Vestnik. (BRODAR-Festschr.) **13—14,** 167—195, 1963. — VÉRTES, L.: "Zitrus"-(Epi-Chopper-) Kulturen in Ungarn. A. RUST-Festschr. 1965a. (In press.) — VÉRTES, L.: Az őskőkor és az átmeneti kőkor emlékei Magyarországon. (Vestiges of the early and intermediate Stone Age in Hungary.) A Magyar Régészet Kézikönyve **I.** Akad. Kiadó, Budapest, 1965b. — VÉRTES, L et al.: Swiatowit. **24,** 159—230, 1962. — VÉRTES, L.: et al. Archaeol. Hungar. **43,** 1—285, 1964. — VOGEL, I. C.—WATERBOLK, H. T.: Groningen radiocarbon dates. IV—V. Radiocarbon **5,** 163—202, **6,** 349—369, 1963—1964. — WOLDSTEDT, P.: Eisz. und Gegenw. **13,** 115—124, 1962.

О РОЛИ ФАУН ПОЗВОНОЧНЫХ И ПАЛЕОЛИТИЧЕСКИХ ПРОМЫШЛЕННЫХ КУЛЬТУР В СТРАТИГРАФИИ ЧЕТВЕРТИЧНОЙ СИСТЕМЫ

М. КРЕЦОИ—Л. ВЕРТЕШ

Резюме

Расчленение четвертичных образований имеет значительные и старые традиции в Венгрии. Это было обусловлено — наряду с известными теориями об оледенениях — прежде всего местными условиями. В соответствии с этим, геологическую историю четвертичного периода можно базировать на верхнеплиоцено-нижнеплейстоценовой и верхнечетвертичной сукцессиях фаун млекопитающих и на разнообразной культурно-исторической документации, которая для последних 50 000 лет контролируется данными археологии и абсолютной хронологии.

На основании фаунистических сукцессий Венгрии после позднеплиоценового чарнотэна были выделены следующие ярусы (более дробно расчлененные горизонты здесь не приводятся): вилланьский и бихарский ярусы в базальном и нижнем плейстоцене, ко второму из которых приурочена промышленная культура Буда с питекантропоидально-гоминидальными реликтами; затем в среднеплейстоценовом отделе наблюдается перерыв; в верхнеплейстоценовом отделе расширение возможностей наблюдения позволило выделить несколько горизонтов, с привлечением соответствующих данных абсолютной хронологии и археологии, из числа которых можно привести фазы Шубайук—Тата, Селета—Токод, Ишталлошкё и Пилишсанто, которые являются наиболее значительными.

VERTEBRATE MICROSTRATIGRAPHY OF THE MIDDLE PLEISTOCENE IN HUNGARY

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The present paper deals with the faunistic characterization of the Hungarian middle Pleistocene, from the basis of the Great or Mindel-Riss or Hoxnian Interglacial to about the end of the Riss or Penultimate Glaciation. Analyses of two sections from Hungarian cave-localities (the rock-shelters of Tarkő and Uppony) are given, including the description of the large Mammals, small Vertebrates, Molluscs and pollen as well as of the deposits of the caves. The climatic fluctuations during the deposition of the sediments as proved by biological and physical data are presented in diagrams. The stages of evolution of the Vertebrates (chiefly small Mammals) confirm the supposed stratigraphic position of the sediments. For the first time in Hungary and in all Europe the existence of two pre-upper Pleistocene *Dicrostonyx* levels could be established, the cold-climate affinities of which was proved by the above-mentioned investigations. The first *Dicrostonyx* level appears to coincide with the Antepenultimate or Mindel and the second one with the Penultimate or Riss Glaciation.

One of the greatest problems of Pleistocene stratigraphy in Europe is the question of the faunistical characterization of the middle Pleistocene, that is, of the interval between the base of the Great or Mindel-Riss or Hoxnian Interglacial and the end of the Riss or Penultimate Glaciation. Stratigraphically well-defined rich middle Pleistocene macrofaunae such as Swanscombe, Ilford, Clacton-on-Sea, Tornewton Cave, etc. in England (SUTCLIFFE 1960, 1962) or Steinheim (ADAM 1954) and probably Achenheim-Hangenbieten (WERNERT 1957) in Germany are few and far between. However, the investigations of the last decades proved the importance in stratigraphy of small-vertebrate faunae particularly in localities where large mammals are scarce (as expounded, to mention only European names, by KORMOS, BRUNNER, HELLER, KRETZOI, I. GROMOV, FEJFAR, JÁNOSSY, etc.). The microfauna, mainly preserved in the form of owl pellets, and obtained from the sediments by washing, constitutes a material sufficient for a statistical examination, and not only for the locality as a whole but for each one of the studied layers. Such a series of deposits gives a clearer picture of the evolution and of the climatic (environmental) changes within the Pleistocene, than the often fragmentary large mammals.

The investigation of such series of deposits has shown that microstratigraphic studies may serve as a basis also of microsystematical work (e.g. the problem of subspecies in Pleistocene taxonomy). On the other hand, the com-

plex investigation of microstratigraphic sequences saves us from the danger of oversimplifying the climatic implications of the faunas, chiefly in the older sections of the Pleistocene. Attention should be paid to Amphibians, Reptiles, Birds, also large Mammals, Molluscs and the deposits should be investigated also by lithologic, mineralogic, and possibly by pollen-analytic techniques.

Some of the excavations by the present writer in the caves of Northern Hungary have been carried out during the last decade according to the above-stressed viewpoints. Of these localities two have yielded middle Pleistocene deposits.

The first of the two is the rock-shelter of the Tarkő (in 850 m altitude above sea level, JÁNOSSY 1962), excavated during the years 1960 to 1964. A shaft of a depth of about twenty metres, filled with red clay (terra rossa), has been emptied by the excavations. The author applied to the extracted fill the washing method of HIBBARD (1949) as modified by himself (JÁNOSSY 1963).

The excavation yielded over 100,000 bones, representing about eighty species. The fauna consists chiefly of microvertebrates, among them a large number of bats. In the upper levels also a macrofauna has been found. The assemblage of large mammals consists of the following species (in the order of decreasing abundance): *Ursus deningeri* REICHENAU, *Capreolus* cf. *süssenbornensis* KAHLKE, *Cervus* cf. *elaphus* L., *Bison* cf. *priscus* BOJ., *Ovis* sp. (small), *Felis* sp. (cf. *Panthera pardus* L.), *Canis lupus mosbachensis* SOERGEL. Elephants and rhinoceroses are lacking, obviously owing to the high altitude of the cave. This assemblage of large mammals in itself is of a lower Pleistocene or early middle Pleistocene type. The quantitative analysis of microvertebrates and plant remains justifies, however, a finer stratigraphic zoning. Fig. 1. represents the changes of relative frequency of the voles (as reflected by the percentual distribution of the number of the molars M_1*); Fig. 2 shows the variations in the abundance of the climatically significant rest of the microvertebrates, *Celtis* seeds, with the percentages referred to the number of vole M_1's at each level, and the results of pollen analysis. Between the layers 1 and 2 there is a faunal and lithologic discontinuity indicating a protracted interruption of sedimentation.

In the diagrams No. 15 is the oldest, No. 1 the youngest level. Pollen has only been found at levels 1 and 8, the rest was sterile.

The faunistic analysis of the section has given the following results:

The fluctuations of the climate, more exactly the shifts of the biotopes are indicated by species representing grasslands and woodlands respectively. At the time of formation of layers 1 to 4 and 12 to 15 the fauna as a whole suggests two drier phases, probably of a wooded-steppe climate with large

* The number of the M_1 varies from 20 to 40 in the lower levels and from 30 to 70 in the upper ones.

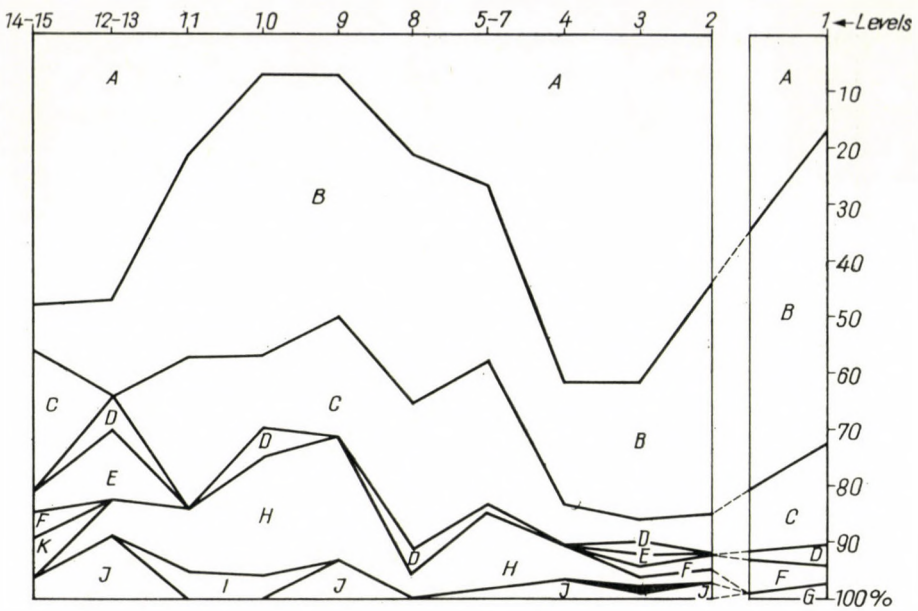

Fig. 1. Relative abundance of vole species in the deposits of the rock-shelter of the Tarkő: (A) *Pitymys arvalidens* KRETZOI, (B) *Microtus arvalinus* HINTON, (C) *Clethrionomys* sp., (D) *Arvicola* sp., (E) *Pitymys gregaloides* HINTON, (F) *Microtus* cf. *gregalis* PALL., (G) *M.* cf. *oeconomus* PALL., (H) *Pliomys episcopalis* MÉH. and *lenki* HELLER, (I) *Lemmus* aff. *lemmus* L., (J) *Lagurus transiens* JÁNOSSY, (black) *Dicrostonyx* sp., (K) *Mimomys intermedius-savini*

numbers of lizards *(Lacerta)*, frequent *Celtis*-seeds, *Bison* among the large Mammals, few if any squirrels *(Sciurus)* , dormouses *(Glis)* and shrews *(Sorex)* . Palaeontological evidence suggests a forest climate for layers 7 to 10 and 11 respectively (large numbers of *Sciurus*, *Glis*, *Sorex*, and the bank vole, *Clethrionomys*, scarce *Lacerta* and *Celtis*-seeds).

The most striking fact from the point of view of ecology is on the one hand the relative frequency of *Microtus arvalinus* HINTON (*"agrestis"*-form (?)) more frequent in the forest phase and of *Pitymys arvalidens* KRETZOI (= *arvaloides* HINTON), more common in the drier phases.* The Recent ecology of the descendants of this species is just the opposite: *Microtus arvalis* PALLAS is a typical grassland form, *Pitymys subterraneus* SÉL.-LONGCH. is a dweller of humid regions. On the other hand, *Allocricetus* seems to be less typical a grassland form than the Cricetines of today. The ecological and palaeoclimatical significance of lemmings at the base of the middle Pleistocene is always uncertain: *Lemmus* looks like a forest type, *Dicrostonyx* like a colder

* The same can be stated on the basis of some lower and middle Pleistocene "vole spectra" (KRETZOI 1956: 218, FEJFAR 1961: 112).

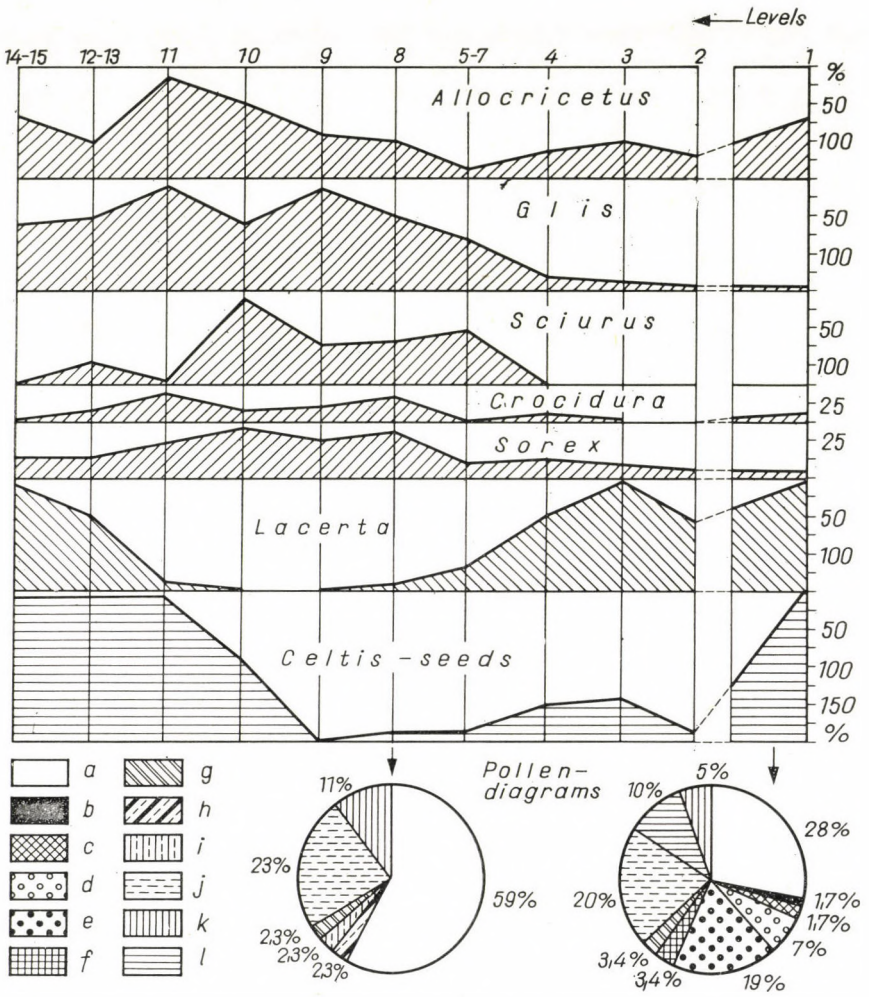

Fig. 2. Relative abundance of climatically significant microvertebrates (voles excepted) and pollen diagrams from the different levels of the rock shelter of the Tarkő. (a) *Pinus*, (b) *Juglans*, (c) *Carpinus*, (d) *Quercus*, (e) *Tilia*, (f) *Alnus*, (g) *Betula*, (h) *Picea*, (i) *Abies*, (J) *Polypodiaceae*, (k) *Gramineae*, (l) *Fungi*

form. The extinct types of *Pliomys* seem to be forest-type animals. The author advanced elsewhere some arguments in favour of *Mimomys intermedius-savini* having been a water-vole (JÁNOSSY 1962a).

There are some non-faunistic reasons for supposing a cooler climate at the time of formation of some levels (chiefly Nos. 2 and 6). These deposits have been found to contain a large quantity of broken stalagmites which may be supposed to have resulted from freezing (see SUTCLIFFE 1962 asf.). This argument is confirmed by the pollen remains (pine, fir and birch) found by

Mrs. M. MIHÁLTZ in the layers 8 or 9, and further by the fact that the red clay gradually turns yellow in the upper levels. Also, the Recent Mediterranean shrew, *Crocidura* is absent from the levels Nos. 2 and 3 (beginning of the Mindel-II. glaciation?). These facts seem to prove the secondary origin of the *terra rossa* in the cave.

The rich pollen-material of level 1 is in striking contrast to the levels below: it indicates a warm climate of interglacial type, including pollen of the oak, linden, hornbeam, and chiefly the walnut. The sediment consists of brown clay and rounded rock detritus. The assumption of the interglacial character of this level finds strong support in the abundant Molluscan remains studied by E. KROLOPP. The stratigraphical position of this layer seems to indicate the beginning of an interglacial (perhaps the Great or Mindel-Riss).

The grain size analysis of the deposits by L. MOLDVAY has established two levels of enrichment of the clay-component, indicating a more moist climate (?) (levels 7 and 12).

The rock-shelter and cave of the Tarkő appears to represent the first locality in Europe where the replacing of the *Mimomys-intermedius-savini* group by *Arvicola* can be observed. *Mimomys* is a typical "index fossil" of the lower Pleistocene. The older part of the section of the rock shelter of the Tarkő (levels 12. to 15.) represents therefore the top of KRETZOI's "Biharian" (1956, 1961 etc.), a transition between the Cromer Forest and Bacton Forest beds of English Pleistocene stratigraphy (ZEUNER 1959: transition from "Cromerian" to "Mosbachian"). The present writer has proposed for the upper part of this section the name "Tarkő-phase", including HELLER's "Brassóicum" (HELLER 1958, JÁNOSSY 1962). A stratigraphic reason for declaring this special phase is provided also by the evolutionary stage of the *Sorex runtonensis* HINTON — *subaraneus* HELLER group, to be discussed below, and by a special transitional form of *Lagurus (L. transiens* JÁNOSSY 1962).

The rock-shelter No. I of Uppony (Northern Hungary), 287 metres above the sea, has initially yielded some fragmentary remains of large mammals of no definite stratigraphic implication (VÉRTES 1949). The washing method provided several thousand microvertebrate bones (JÁNOSSY 1965). The rich material proved the lowest levels to be typically lower Pleistocene, "lower Biharian" according to KRETZOI. After a sharp faunal break there follow eight levels of middle Pleistocene. The large-mammal assemblage of the upper layers (Nos. 1 to 3) of this section consists of *Ursus* sp. (probably a smaller form of *U. spelaeus* ROS.), *Felis* sp. I—II. (a larger lion and a smaller one, possibly a robust panther), *Canis lupus* L., *Cervus elaphus* L., *Capreolus capreolus* L. (big), *Ovis* sp. (a big form related to the *Ovis ammon-polii* group of Central Asia) and *Bison priscus* BOJ. (big). Except for the big sheep, this looks like a very common younger Pleistocene fauna that could be upper Pleistocene just as well.

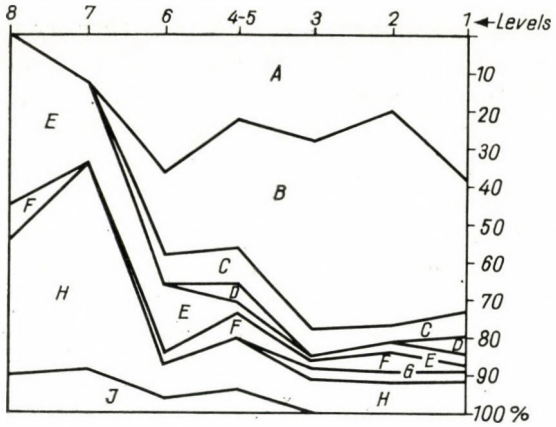

Fig. 3. Relative abundance of vole species in the deposits of the rock-shelter. No. 1 of Uppony. (A) *Microtus arvalis* PALL., (B) *M. gregalis* PALL., (C) *M. oeconomus* PALL., (D) *M. nivalis* MONTIN, (E) *Pitymys arvalidens* KRETZOI, (F) *Arvicola greeni-praeceptor* HINTON group, (G) *Dicrostonyx torquatus* group, (H) *Clethrionomys* sp., (J) *Pliomys* sp.

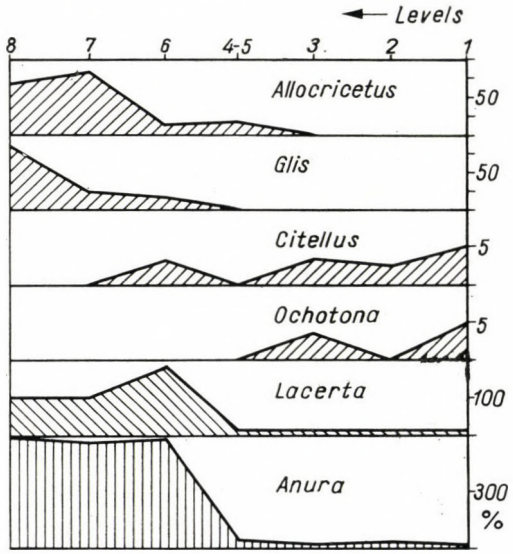

Fig. 4. Relative abundance of climatically significant microvertebrates (voles excepted) in the deposits of the rock-shelter No. I of Uppony

The diagram prepared under the observation of the same viewpoints as the foregoing one indicates once more a marked change from forest conditions to cold grasslands. The predominance of *Clethrionomys*, *Pitymys*, frogs *(Anura)* and the presence of the dormouse *(Glis)* in the levels 7 and 8 together with the relic *Pliomys* is in a striking contrast with the dominance of the Sibirian vole *(Microtus gregalis)* and with the presence of the root vole *(M. oeconomus)*, the snow vole *(M. nivalis)* the collared lemming *(Dicrostonyx)* , the spermo-

phile *(Citellus)* , the pika *(Ochotona)* and the ptarmigan *(Lagopus lagopus)* in the upper levels, Nos. 1 to 3. The ecology of these species in the upper part of the middle Pleistocene seems to have been much the same as that of their Recent descendants.

The upper part of the section consists of a bright yellow clay with partly angular debris, the lower part of brown clay with rounded stones. The section has yielded no pollen. However, *Celtis*-seeds sporadically occur throughout the whole section. The rich Molluscan fauna studied by E. KROLOPP confirms the colder climate of the upper levels.

The special form of the common shrew, *Sorex araneus macrognathus* JÁNOSSY 1965 (see below) and the spermophile *(Citellus major*-group), the

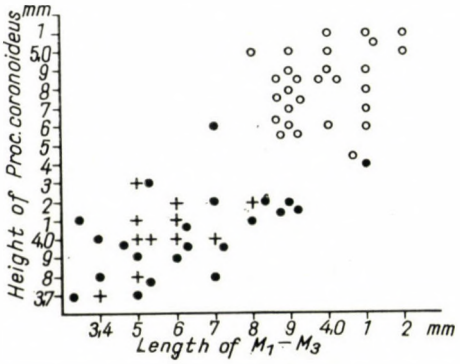

Fig. 5. Scatter diagram showing the size of the mandible of the *Sorex araneus*-group *vs.*time during the middle Pleistocene. Crosses: *Sorex runtonensis* HINTON, Cromer Forest Bed, full circles: *S.* cf. *subaraneus*, HELLER, Tarkő; empty circles: *S. araneus macrognathus* JÁNOSSY, Uppony and from another locality of the same age in Hungary (Solymár)

presence of the voles belonging to the *Arvicola greeni — praeceptor* group and of the big sheep (nowhere found so far in the rich Hungarian lower and upper Pleistocene faunae) exclude the Cromerian or Eemian-Würm age of the upper-level fauna. The microfaunistic and lithologic evidence suggests a colder climate, a glacial period, presumably the Riss or Penultimate Glaciation (Riss I, phase of Steinheim).

Numerous measurements on micromammal bones, especially on the mandibles of the shrews of the *Sorex araneus*-group *(Sorex runtonensis* HINTON from the Cromer Forest Bed of England, — [in the British Museum, N. H., by kind permission of Dr. A. J. SUTCLIFFE] — *S.* cf. *subaraneus* HELLER from the rock-shelter of the Tarkő and *S. araneus* described by the author as *S. araneus macrognathus* JÁNOSSY 1964 from Uppony: see Fig. 5) have revealed the growth of the mandibles with time.

The macrofaunistically proved pre-upper Pleistocene cold spells (the appearance of *Rangifer* and other cold forms at Mosbach, Süssenborn, Fran-

kenhausen, etc. — [KAHLKE 1963] — Achenheim — [WERNERT 1957] — Tornewton Cave, Glutton stratum — [SUTCLIFFE 1962] — Châtillon-Saint-Jean — [BOURDIER 1954], cold oscillations assumed by KURTÉN on a faunistic basis in 1961 etc.) find strong support in the above-described complex investigations. The discovery of pre-Würm "*Dicrostonyx*-levels" in Europe (see also FEJFAR 1961, HELLER 1963) constitutes a clear microfaunistic proof of the polyglacialistic theories. These data seem to complete the gaps in the otherwise nearly continuous rich series of microvertebrate profiles in Hungary covering the range from the upper Pliocene to the Antepenultimate Glaciation and the upper Pleistocene (KRETZOI 1961, JÁNOSSY 1964 etc.).

REFERENCES

ADAM, K. D.: Quaternaria **1,** 131—144, 1954. — BOURDIER, F.: Bull. Soc. Géol. France, C. R. Sommaires des Séances, **3,** 76—80, 1954. — FEJFAR, O.: Review of Quarternary Vertebrata in Czechoslovakia. Czwartozęd Europy Srodkowej i Wschodniej. INQUA, Warszawa **1,** 109—118, 1961. — HELLER, F.: Neues Jahrb. f. Geol. u. Pal. Abh. **107,** 1—102, 1958. — HELLER, F.: Eiszeitalter und Gegenwart **14,** 111—116, 1963. — HIBBARD, C. W.: Contrib. Mus. Paleont. Univ. Michigan **8,** 7—19, 1949. — JÁNOSSY, D.: Annales Hist.-Nat. Mus. Nat. Hung. **54,** 155—176, 1962. — JÁNOSSY, D.: Állattani Közlemények **49,** 63—74, 1962a. — JÁNOSSY, D.: Annales Hist.-Nat. Mus. Nat. Hung. **55,** 109—141, 1963. — JÁNOSSY, D.: Karszt- és Barlangkutatás (In press). 1965. — JÁNOSSY, D.: Acta Zoologica, Budapest **10,** 139—197, 1964a. — KAHLKE, H. D.: Paläont. Zeitschr. Stuttgart **37,** 277—282, 1963. — KURTÉN, B.: Commentationes Biol. Soc. Sci. Fennica. Helsingsfors **21,** 1—62, 1960. — KRETZOI, M.: Geologica Hungarica **27,** 1—264, 1956. — KRETZOI, M.: Stand der ungarischen Quartärforschung. Stratigraphie und Chronologie, Czwartozęd Europy Srodkowej i Wschodniej. INQUA, Warszawa **1,** 313—332, 1961. — SUTCLIFFE, A.: Transactions of Torquay Nat. Hist. Soc. **13,** 1—28, 1960. — SUTCLIFFE, A.—ZEUNER, F. E.: Proc. Devon Archaeol. Explor. Soc. **5,** 127—145, 1962. — VÉRTES, L.: Földtani Közlöny **80,** 409—416, 1950. — WERNERT, P.: Mém. Serv. Carte Géol. d'Alsace et de Lorranie **14,** 1—262, 1957. — ZEUNER, F. E.: The Pleistocene Period. Hutchinson, London, 1959.

МИКРОСТРАТИГРАФИЧЕСКОЕ РАСЧЛЕНЕНИЕ СРЕДНЕГО ПЛЕЙСТОЦЕНА НА ОСНОВАНИИ ПОЗВОНОЧНЫХ В ВЕНГРИИ

Д. ЯНОШШИ

Резюме

В настоящей работе дается фаунистическая характеристика среднеплейстоценовых отложений Венгрии (под средним плейстоценом здесь подразумевается период от начала межледниковья миндель-рисс до конца рисского оледенения). При этом рассматривается изучение толщи двух пещерных обнажений (каменные ниши Таркё и Уппонь) путем комплексних исследований. Наряду с мелкими позвоночными большое внимание уделилось также и находкам крупных млекопитающих и моллюсков; изучались растительные остатки (семена Celtis, пыльца), а также производились литологический, минералогический и педологический анализы осадочных пород. Климатические изменения продемонстрировались фаунистическими диаграммами, обоснованными физическими данными. Установленное стратиграфическое положение подтверждается главным образом степенью филогенетического развития мелких млекопитающих. Впервые в Венгрии — и во всей Европе — удалось доказать в пределах сравнительно небольшого района (горы Бюкк) наличие двух «горизонтов с Dicrostonyx», которые древнее верхнего плейстоцена и о холодной природе которых свидетельствуют результаты комплексных исследований. Ряд данных дает судить о полной вероятности того, что рассматриваемый в настоящей работе первый, более древний горизонт «копытних леммингов» следовало бы отнести к миндельскому оледенению, а второй, более молодой — к рисскому оледенению.

MOLLUSC FAUNA OF THE SEDIMENTARY FORMATIONS OF THE QUATERNARY PERIOD, HUNGARY

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Historical developments in the research concerning the Quaternary molluscs of Hungary are presented. The former techniques of sample picking were superseded by the quantitative study of faunae washed out of the rock formations as the lately initiated characteristic technique of the microstratigraphic studies. By this latter technique a huge volume of information was accumulated. In the light of this information the author feels optimistic about the utility of the mollusc faunae in deciding problems of Pleistocene chronology, as against the pessimism voiced earlier in this respect

The paper further deals with the main stages of evolution of the mollusc fauna in the Quaternary.

The calcium carbonate shell of the molluscs is well suited to fossilization. The majority of the fossils yielded by the Quaternary formations consists of *Gastropods* and *Bivalves*. In consequence, the malacofaunistic approach is quite promising in solving the stratigraphic and chronologic problems met with in the Quaternary formations.

The first data concerning the Quaternary mollusc fauna of Hungary were furnished by LÓCZY (1887) and H. HORUSITZKY (1909). Although these authors recognized the similarity between the mollusc fauna from the Recent and Pleistocene for stratigraphic reasons they were likely to emphasize the differences rather than the similarities. The first attempts at a more detailed zoning of the molluscs were made by WEISS (1911) and KORMOS (1910, 1911a, 1911b). It was especially KORMOS who drew a series of highly appropriate conclusions in respect of the ancient conditions of climate and environment from the analogies between Recent, Holocene and Pleistocene faunae.

Based on gradually accumulated voluminous data particularly concerning the early Pleistocene faunae considered "praeglacial" according to the monoglacialistic standpoint of those times, SOÓS (1926) in the form of a review summed up the information concerning the origin and evolution of the mollusc fauna of Hungary. He emphasized the close similarity between the "praeglacial" faunae and the fauna of today ("periglacial" stood for the pre-Würm faunae of interglacial type). According to SOÓS, strictly speaking, the Pleistocene fauna (Riss and Würm faunae) differs from the Recent fauna in that certain species stretching towards the south or completely disappearing, were replaced by other expanding from the north towards the south, that is, the invasion was

by species migrating from the mountains to the plains, but these in turn also withdrew when the climate once more become warmer.

Besides the study of the early Pleistocene interglacial faunae also that of the younger loess faunae could boast of some interesting achievements, as is reflected in the work of J. MURÁNYI (1922—1925) and particularly in that of M. ROTARIDES. Concerning the gastropod fauna of the loess, ROTARIDES stated in his comprehensive treatise (1931) that the assemblage consisted of species of large-scale ecologic tolerance and considerable areal extent, which are frequent at present too, a few are associated as accessory species, but are now extinct in the Carpathian Basin. ROTARIDES considered the individual localities as small-biotopes and compared them with the biotopes of today. It was in this way that he pointed out the possibility of distinguishing microfacies by their mollusc fauna, a working hypothesis still generally accepted in Pleistocene molluscan research.

With the advance of the polyglacialistic conception there arose the demand for a finer stratigraphic zoning. In the lack of sufficient quantitative data ROTARIDES could not possibly have distinguished the individual phases of the Pleistocene by their molluscan assemblages. Thus he concluded (ROTARIDES 1942) that it is futile to rely on the molluscs in respect of the zoning of the Pleistocene since they can only serve as paleoecologic indicators.

This pessimistic attitude was based besides the lack of quantitative data on the fact that the knowledge concerning the Pleistocene molluscs tremendously increased in volume and thus the hemerae of an ever increasing number of species were recognized to transgress the duration of the individual phases of the Pleistocene. Consequently, the number of "index fossils" decreased more and more. Simultaneously, the study of the more rapidly changing vertebrates furnished important stratigraphic clues (KRETZOI 1937—36 etc.).

After a small pause, the studies of BARTHA and HORVÁTH (both 1954) lent a renewed impetus to the Quaternary malacologic research. The application of the methods of collection and evaluation (the quantitative study of a complete series of samples taken at close-spaced points) as adapted to malacological studies in the Quaternary (KROLOPP 1961b) revealed that slight changes of the ecologic conditions hardly affected the composition of the faunae whereas they considerably modified the percentual distribution of the individual species constituting the fauna. Consequently, the sequence of the variations of the dominance values of the species lends itself to a correlation of the oscillations of the ecologic conditions in general and of the climate in particular.

The quantitative evaluation of the Quaternary mollusc faunae by HORVÁTH (1954, 1963) and KROLOPP (1961a, 1961b, 1964a, 1964b), as well as later on by BARTHA (1964), SZÓNOKY (1963) and MUCSI (1963, 1964) resulted in some remarkable positive results, such as the distinction of the climatic phases of

the Pleistocene and the determination of the climatic parameters on the basis of comparison with Recent assemblages of known ecology. It is to be hoped that with the accumulation of more data the accuracy of the chronological subdivisions will also increase.

In the following the author shall enumerate the Quaternary formations that furnished mollusc faunae of some importance.

I. Terrestrial formations

1. *Loess, wind-borne sand and their altered varieties*

Publications concerning mollusc loess faunae collected from all over Hungary are numerous (ROTARIDES 1931). However, the molluscs described were mostly collected by the early techniques of picking, which neglected the small-sized species. The early lists of species thus have to be dealt with with some caution. The frequency data — if such were given at all — serve at best only as a basis of a first orientation.

The latest quantitative biostratigraphic studies on loess faunae were mostly aimed at Würm or occasionally at Riss loesses. It was only at Paks that HORVÁTH proved the presence of older assemblages classed as Mindel and Günz (HORVÁTH 1954).

The wind-blown sands of Hungary mostly contain but a sparse gastropod fauna, whereas those of an intermediate type (loessy sand, sandy loess) are all the richer.

Altered loess (loam and fossil soil zones) was considered on the basis of earlier data as sterile, but recent studies have proved the presence of a characteristic assemblage of species (KROLOPP 1965).

2. *Cave deposits and fissure fillings*

From the cave deposits of Hungary, data concerning molluscs are few. This is partly due to inadequate collecting techniques (washing was but lately introduced) and particularly due to the fact that the deep, long caves are not a favourable milieu for gastropods. The faunae furnished by the Hungarian caves are of diverse of ages within the Quaternary (Tarkő: KROLOPP *in* JÁNOSSY 1962, Solymár: ROTARIDES 1942, both Mindel-Riss interglacial, Lambrecht cave: KROLOPP 1964b, Riss-Würm interglacial, Tarkő: Holocene etc.).

Also the fissure fillings may furnish valuable evidence. The mollusc fauna accompanying the rich lower Pleistocene vertebrate fauna gleaned from the fissures of the Villány Mountains is unfortunately rather sparse although of a considerable importance to the reconstruction of Molluscan evolution (KRETZOI 1956, KROLOPP *in* KRETZOI 1962). A richer fauna was found in the Riss-Würm interglacial material of the Süttő crevice (KORMOS 1925).

II. Fluvial deposits

In the coarser fluvial deposits Molluscs are of course rather scarce, but the finer sands and particularly the floodplain silts frequently contain abundant mollusc faunae. The Kisláng fauna of Günz age together with the rich vertebrate fauna was derived as well as the likewise lower Pleistocene Városhídvégfauna (KORMOS 1911a) from a gravelly and sandy series of deposits (SOÓS *in* KRETZOI 1954).

As to the finer-grained sediments, rich faunae representing diverse phases of the Pleistocene were furnished by the deep wells sunk in the Great Plains (BARTHA 1962). The fauna accompanying the prehistoric occupational site of Szekszárd was enclosed in a late Würm, Holocene floodplain deposit (KROLOPP 1962).

III. Standing-water deposits

1. *Lacustrine sand, silt, clay*

Only a few of the faunae furnished by this type of strata have been treated in detail as yet. One of these is the fauna of the upper Pleistocene (partly perhaps middle Pleistocene) series of the "Sáfránykert beds" near Lake Balaton and part of the material furnished by the deep wells in the Great Plains (BARTHA 1962).

2. *Lake chalk (calcareous mud)*

This is a deposit laid down in the lime-rich waters of shallow lakes particularly in the Holocene. Holocene faunae were described from the calcareous muds of the Kiskunság (MUCSI 1963, 1964) and from that of the Sárrét (KROLOPP 1965) earlier believed to be Pleistocene (KORMOS 1911c).

3. *Peat and muck*

The study of the locally fairly rich faunae of the muck and turf deposits, although rather promising, has been more or less neglected up to the present. Faunae from this type of deposits were described from the Sárrét by KORMOS (1911c), from the Nagyberek by KORMOS (1911d) and from the turfy area between Baja and Kecel (RICHNOVSZKY 1962).

IV. Hot spring deposits

The travertine and calcareous mud deposited by the hot springs furnished a rich mollusc fauna of terrestrial as well as aqueous habitat, in a fair state of preservation. These faunae, discovered mostly in the last few years, largely belong to the interstadial and interglacial phases of the Pleistocene. Particular mention should be made of the faunae whose age is confirmed by accompanying vertebrates. (The faunae from the environment of Buda, of Günz-Mindel

and Mindel age: KROLOPP 1962; the late Mindel fauna of Vértesszöllős: KROLOPP *in* KRETZOI—VÉRTES 1964; and the Riss-Würm and early Würm fauna of Tata: KROLOPP 1964a.) These faunae, statistically speaking, make important contributions to the Pleistocene history of the Hungarian molluscs.

The faunae known till this day from the Pleistocene deposits of Hungary are as yet insufficient to form a coherent picture of the Quaternary evolution of the molluscs. Information is particularly scanty concerning the middle Pleistocene and the Holocene. The outlines of the evolution can, however, be given roughly as follows:

It has not yet been possible to bridge the gap between the late Pannonian fauna (containing a number of still existing species, but of a nonetheless unfamiliar aspect) and the earliest Pleistocene by an appropriate Astian fauna. Amongst our late Pliocene faunae consisting of a few species (Csarnóta: KRETZOI 1962) alien, Mediterranean elements are still found *(Cochlostoma* sp., *Chondrina* sp., very large *Limacids)* besides the familiar Recent ones (e.g. *Laciniaria plicata, Abida frumentum)*. The scanty terrestrial elements of the early Günz (upper Villányian) fauna of Kisláng are mostly steppe forms still common today *(Abida frumentum, Helicella hungarica)* whereas the water fauna consists of persistent Pelliocene ements *(Viviparus böckhi, Tylopoma* sp., KRETZOI 1954). The Városhídvég fauna whose water assemblage accompanied by indifferent terrestrial species still contains *Hydrobia longaeva, Theodoxus prévostianus* and *Corbicula fluminalis* (KORMOS 1911a) is presumably of the same age.

The aforementioned faunae from the fissures of the Villány Mountains (Praegünz and Günz = Villányian) consist but of a few species still living today. The mollusc fauna of the Günz-Mindel (lower Biharian = Cromerian) is well known from the hot-spring deposits around the capital of Hungary. It is the younger phase of the Günz-Mindel interstadial that is most abundantly represented in these assemblages, which remarkably resemble the present-day fauna of the Hungarian Mountains (KROLOPP 1958, 1962). Besides steppean and xerothermous elements *(Abida frumentum, Helicella hungarica)*, there are also forest forms *(Cochlodina laminata, Aegopinella nitens)* and ubiquitous ones *(Vallonia pulchella, Vertigo pygmaea)*. Not a single psychrophilous form has been encountered. Besides the xerothermous elements there occur several typically interglacial species: *Truncatellina claustralis, Vertigo moulinsiana, Acanthinula aculeata, Helix pomatia)*. An interesting colour is added by two extinct species, the Tertiary relic, *Gastrocopta serotina* and *Zonitoides sepultus*. Both have lately been described by LOŽEK from the lower Pleistocene of Czechoslovakia (1964).

The younger horizons of the hot-spring series of Buda already represent the Mindel (upper Biharian). The interglacial species disappear and the once dominant xerothermous steppean species are considerably on the decline.

Besides the ubiquitous forms, species of considerable cold tolerance or pronounced psichrophilous character crop up. These also occur in the loess fauna *(Vallonia tenuilabris, Orcula dolium, Goniodiscus ruderatus, Trichia striolata, Arianta arbustorum, Perforatella bidnes)*. The late Mindel (upper Biharian) mollusc fauna accompanying the occupation site of Vértesszöllős (KROLOPP *in* KRETZOI—VÉRTES 1964) presents a similar aspect.

Data from the middle Pleistocene are scanty. The Mindel-Riss (Hoxnian) interglacial is marked by *Aegopis verticillus* (Solymár), *Helicodonta obvoluta* (Solymár, Tarkő), *Chondrina clienta* (Tarkő), *Vitrina annularis* (Tarkő). Rissian glacial faunae have been described besides these from the aforementioned deep wells in the Great Plains, (HORVÁTH—ANTALFFY 1954) only from Paks (HORVÁTH 1954) and Kulcs (BARTHA—KROLOPP 1965). However, this fauna can but very tentatively be distinguished from the loess faunae of the Würm.

A "Banatica" fauna characteristic of the Riss-Würm (Eem) interglacial was unknown until recently from the caves. Lately, however, the Lambrecht cave in the Bükk Mountains furnished *Helicigona banatica, Mastus bielzi, Monachoides vicina, Perforatella dibothryon, Isognomostoma isognomostoma*, etc (KROLOPP 1964b). The Riss-Würm fauna from the deeper-lying regions of Hungary is less characteristic and *Helicigona banatica* too is absent (Tata: KROLOPP 1964a, Süttő: KORMOS 1925).

In the early Würm (Tata: KROLOPP 1964a), (Csolnok: KROLOPP 1964) there still occur species of elevated humidity requirements and preference for warmth which, lacking in the loess faunae of subsequent times, crop up only in the Holocene again (e.g. *Vertigo antivertigo, Vertigo angustior, Vallonia enniensis, Clausilia pumila, Carychium minimum)*. The fauna of the later stages of the Würm consists of a relatively small number of tundra, steppe and wooded-steppe elements. These faunae cannot, however, be distinguished except by the quantitative studies performed in the last few years. Thus, e.g. in the loess profile containing several intercalations of fossil soil of the Mecsek Mountains, the fauna, although dominated by *Pupilla muscorum, Vallonia costata* and *Succinea oblonga*, also comprises a number of wooded-steppe elements *(Orcula dolium, Clausilia dubia, Arianta arbustorum)* in the lowest loess layer ($Würm_1$?). The fauna of the succeeding layer ($Würm_2$?) is a steppe fauna indicating a drier, warmer climate *(Pupilla triplicata, Chondrula tridens, Helicella hungarica*, etc.). The youngest loess ($Würm_3$?) is characterized by the dominance of the psychrophilous *Columella columella, Pupilla sterri, Vallonia tenuilabris* and *Succinea oblonga* and by the lack of the thermophilous elements (KROLOPP 1964.)

Whether this succession corresponds to the succession of "Pupilla"-, "Striata"- and "Columella"-faunae recognized by LOŽEK (1955) and abundantly documented on Czechoslovakian material, is to be decided by further

research. Little is known of the evolution of the Holocene fauna of Hungary. The fauna accompanying the occupational site of Szekszárd, set at the very end of the Pleistocene, lacks the psychrophilous elements (KROLOPP 1962) such as *Vallonia tenuilabris*, *Columella columella*, but among the water Gastropods there still occur species of northerly extension which hardly attain here in Hungary the boundaries of the faunal region today. *(Valvata pulchella*, *Gyraulus riparius.)* A late Pleistocene-early Holocene *Valvata puchella* horizon is also suggested by other data (KORMOS 1911a, 1911c). Further data (KORMOS 1911c, 1911d, MUCSI 1963, KROLOPP 1964) referring to the subsequent warmer spell (Atlantic phase?) are also available. However, a more detailed zoning of the Holocene on the basis of the mollusc fauna will have to be preceded by the thorough study of a large number of localities.

Based on the data so far set out, the evolution of the Quaternary mollusc faunae of the Hungarian region may be subdivided as follows:

1. Pre-Günz—Günz (Villányian). The dryland fauna is little known. In the water fauna the species living today are accompanied by Tertiary relics (Kisláng, Városhídvég).

2. Günz-Mindel (cf. lower Biharian). The fauna greatly resembles that of today except for a few extinct species also occurring elsewhere in the lower Pleistocene of Central Europe (calcareous mud deposits of the Buda region, Villány).

3. Mindel (cf. upper Biharian). First reliable data concerning the appearance of psychrophilous forms of northerly extension (younger horizon of the calcareous mud deposits around Buda, Vértesszöllős).

4. Mindel-Riss (Hoxnian). The fauna much resembles that of today, with some species of southerly, southeasterly extension (Tarkő, Solymár).

5. Riss. The little-known fauna resembles, based on available scanty data, the loess fauna of the Würm (Solymár, Paks, Kulcs).

6. Riss-Würm (Eemian). This is a pronouncedly interglacial fauna, consisting of species not present in the present-day assemblage or at best just attaining the faunal region from the south and the southwest as far as Hungary is concerned. (Lambrecht cave, Tata, Süttő.)

7. Würm. The early fauna still suggests a mild, humid climate (Tata, Csolnok); somewhat later there appear the boreo-alpine and extinct species not represented in the fauna of today. Alternation of tundra, steppe and wooded-steppe type faunae (Paks, Kulcs, the Mecsek region, the Dorog basin and numerous older data).

8. Holocene. The evolution of the fauna is little known in its details. At the beginning of the period the water fauna is still dominated by pyschrophilous elements, whereas the percentage distribution of the species suggests an association indicating a climate somewhat warmer than the present for the subsequent period

REFERENCES

BARTHA, F.: Magyar Áll. Földtani Int. Évkönyve **14,** 167—205. 1954. — BARTHA, F.: Magyar Áll. Földtani Int. Évi Jelentése 1959-ről, 271—295, 1962. — BARTHA, F.: Magyar Áll. Földtani Int. Évi Jelentése 1961-ről, 407—415, 1964. — BARTHA, F.—KROLOPP, E.: Magyar Földtani Int. Évi Jelentése 1962-ről. (Under preparation.) — HORUSITZKY, H.: Földtani Közlöny **39,** 135—143, 1909. — HORVÁTH, A.: Állattani Közl. **44,** 171—184, 1954. — HORVÁTH, A.: Acta Biol. Szeged **8,** (Ser. nov.), 173—192, 1962. — HORVÁTH, A.—ANTALFFY, S.: Ann. Biol. Univ. Hung. **2,** 417—428, 1954. — JÁNOSSY, D.: Ann. Hist.-Nat. Mus. Nat. Hung. **54,** 155—176, 1962. — KORMOS, T.: Földt. Int. Népszerű Kiadv. **2,** 1910. — KORMOS, T.: A Balaton tud. tan. eredm. **1,** 1, 1911a. — KORMOS, T.: A Balaton tud. tan. eredm. **1,** 1, 1911b. — KORMOS, T.: A Balaton tud. tan. eredm. **1,** 1, 1911c. — KORMOS, T.: A Balaton tud. tan. eredm. **1,** 1, 1911d. — KORMOS, T.: Állattani Közl. **22,** 139—175, 1925. — KRETZOI, M.: Geol. Hung. Ser. Pal. **27,** 1—264, 1956. — KRETZOI, M.: Földtani Intézet Évi Jel. 1953-ról, 213—265, 1954. — KRETZOI, M.: Földtani Intézet Évi Jel. 1959-ről, 297—395. 1962. — KRETZOI, ZOI, M.—VÉRTES, L.: Acta Geologica **8,** 313—317, 1964. — KROLOPP, E.: Állattani Közl. **46,** 245—253, 1958. — KROLOPP, E.: Földtani Intézet Évi Jel. 1957—58-ról, 508—511. 1961a. — KROLOPP, E.: A Buda-környéki alsó-pleisztocén mésziszapok csigafaunájának állatföldrajzi és ökológiai vizsgálata. (Zoogeographic and ecologic study of the Gastropod fauna of the lower Pleistocene calcareous mud deposits around Buda.) Thesis. 1961b. (Manuscript). — KROLOPP, E.: Swiatowit **24,** 203—210, 1962. — KROLOPP, E.: Arch. Hung. **43,** 87—103, 1964a. — KROLOPP, E.: Földtani Intézet Évi Jel. 1963-ról. (In press). — KROLOPP, E.: Ann. Hist.-Nat. Mus. Nat. Hung. **56,** 185—188, 1964b. — KROLOPP, E.: Földtani Intézet Évi Jelentése 1964-ről. (In press). KROLOPP, E.: A sárréti mésziszap Mollusca-faunájának kvantitatív vizsgálata. (Quantitative study of the Mollusca fauna of the calcareous mud deposits of the Sárrét.) (Manuscript). — LÓCZY, L. sen.: Földtani Intézet Jelentése 1886-ról, 99—116, 1887. — LOŽEK, V.: Rozprávi Ustredniho Ustavu geologického. **17,** 1—510, 1955. — LOŽEK, V.: Arch. f. Moll. **93,** 5—6. 1964. — MUCSI, M.: Földtani Közlöny **93,** 373—386, 1963. — MUCSI, M.: Hidrológiai Közlöny **10,** 463—471, 1964. — MURÁNYI, J.: Barlangkutatás **10—13,** 17—23, 1922—25. — RICHNOVSZKY, A.—KOVÁCS, GY.: Opusc. Zool. **4,** 133—144, 1962. — ROTARIDES, M.: Alföldkut. Biz. Könyvt. **8,** A/8, 1—181, 1931. — ROTARIDES, M.: Földtani Közlöny **72,** 171—180, 1942. — SOÓS, L.: Ann. Mus. Hung. **24,** 392—421, 1926. — SZÓNOKY, M.: Földtani Közlöny **93,** 235—243, 1963. — WEISS, A.: A Balaton Tud. Tanulm. Eredm. **1,** 1, 1911.

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А. КРОЛОПП

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VORLÄUFIGES ÜBER QUANTITATIVE KLASSIFIZIERUNG DER SUBALKALISCHEN ORTHOMAGMATITEN

Von

D. GIUŞCĂ und E. SZÁDECZKY-KARDOSS

UNIVERSITÄT, BUCUREŞTI EÖTVÖS UNIVERSITÄT, BUDAPEST

Der orthomagmatische Gesteinsbereich — ohne Ultrabasite — wird in fünf horizontalen Schnitten des Johannsenschen Doppeltetraeders projiziert, die nach ihrem Mafitgehalt in zwei Hauptserien mit 0—30 und 30—70% Mafitgehalt unterteilt werden. Die mafitarme Hauptserie wird dann — ohne weitere Projektion — in zwei Unterserien eingeteilt: aplitisch-plagioklasitische Gesteine mit weniger als 10% Mafit und normale Orthomagmatite mit 10—30% Mafit, wobei ihre Unterscheidung mit dem Suffix Aplit (oder Aplo) in der Unterserie 0—10% Mafit erfolgt. Die Gesteine mit mehr als 70% Mafit (d. h. die Ultrabasite) werden in einem Extratetraeder mit den Polen 1. Fe-Mg-pyroxene, 2. Ca-pyroxene — Ca-amphibole, 3. Alkalipyroxene — Alkaliamphibole — Glimmer und 4. Erzmineralien projiziert, wobei Olivin an die Kante Erzmineralien Fe—Mg-pyroxene zu liegen kommt (Abb. 2—5). Diese Projektion ermöglicht die klare Unterscheidung selbst der kali-, natron-, kalk- und der verschiedenen Mg-Fe-betonten Gesteine.

Auf Grund der Konrgrößenverteilungskurven (Abb. 6) werden die Orthomagmatite in 8 Gruppen eingeteilt: *A)* Etwa gleichkörnige Magmatite: grobkörnige »Intrusiva« (Median über 5 mm), normale (5—1 mm), feinkörnige (1—0,1 mm) und Mikrointrusiva (Median unter 0,1 mm) und *B)* ungleichkörnige oder glasige Vulkanite mit 3 Untergruppen: normale Vulkanite (Median unter 1 mm), Mikrovulkanite (0,1—0,001 mm), Hyalovulkanite (Median unter 0,001 mm). Die achte Gruppe bilden die porphyr-(it)ischen Gesteine mit ungleichmäßiger Korngröße, aber mit etwa isometrischem Habitus.

Eine eindeutige beschreibende Klassifizierung und Abgrenzung der zum Teil heteromorphen magmatischen Gesteine kann auf Grund der modalen mineralogischen Zusammensetzung und der Struktur erfolgen. Die im folgenden vorgeschlagene quantitative Nomenklatur beruht auf dieser doppelten Grundlage. Wenn die modale mineralogische Zusammensetzung z. B. infolge eines Glasgehaltes nicht festgestellt werden kann, dann gebraucht man die auf die übliche Art aus der chemischen Analyse berechnete oder nötigenfalls die aus dem Brechungsindex des Glases geschätzte Norm.*

Zur quantitativen Abgrenzung und Darstellung der mineralogischen Zusammensetzung bewährte sich meistens das JOHANNSEN Doppeltetraeder, doch führten dessen bisherige Vereinfachungen zu einem Doppeldreieck durch Reduktion der Feldspate zu Plagioklas und Alkalifeldspat oder zu Anorthit und Alkalifeldspat, schließlich zur Verschleierung wichtiger Verwandtschaftsverhältnisse. Durch die Summation Plagioklas-Alkalifeldspat (Abb.1) werden die bedeutendsten und teilweise wesenfremden Gesteinsgruppen Gabbro,

* Man kann sogar auf Grund eines neuen Berechnungsverfahrens (siehe Acta Geologica X. 1966.) verschiedene heteromorphe mineralische Zusammensetzungen unmittelbar aus den analytisch ermittelten Gewichtsprozenten der chemischen Analyse berechnen.

Diorit, Basalt, Andesit, Anorthit bis Oligoklasit in einer einzigen gemeinsamen Ecke der Doppeldreieckprojektion unauflösbar zusammengedrängt. Durch die Summation Anorthit-Alkalifeldspat wird dagegen der Unterschied zwischen Kali- und Natrongesteinen verschleiert. Man kann auf diese Weise stets nur inhomogene grobe Kategorien unterscheiden.

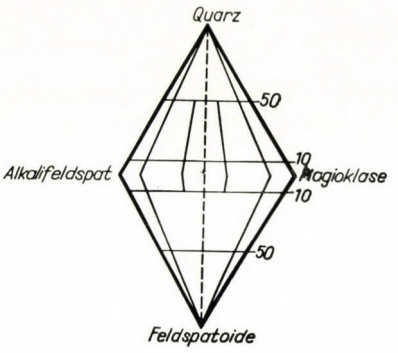

Abb. 1

In solchen Vereinfachungen äußert sich der Wunsch, die Orthomagmatiten durch ein möglichst einfaches Bild darzustellen. Die Komplexität dieser Gesteine kann aber nach dem heutigen Stand der Erkenntnis einen entsprechenden Ausdruck nur in gewissermaßen komplexen Diagrammen finden.

Entsprechend wird im folgenden das Doppeltetraeder in nicht reduzierter Form, d. h. unter Absonderungen der Kali-, Natron- und Kalziumfeldspate gebraucht. Die Darstellung kann dann in fünf horizontalen Schnitten des Doppeltetraeders eindeutig vorgenommen werden (Abb. 2). Die einzelnen Schnitte repräsentieren die Felder mit

100 bis 50%
50 bis 10%
10 bis — 10%
—10 bis — 50%
—50 bis —100% Quarzgehalt.

Solcherart wird auch die Abtrennung der bisher in einem einzigen Pol vereinigten 3 Hauptgruppen der Feldspatoiden — Nefelin (mit der Sodalitgruppe), Leucit und Melilite — auf die in Abb. 2 dargestellte Weise ermöglicht.*

* Allerdings wird dann z. B. zwischen 100% Leucit und 50% Kalifeldspat + 50% Nefelin bzw. 100% Melilit und 50% Anorthit + 50% Nefelin kein Unterschied gemacht. Diese Unterschiede haben aber infolge der gegenseitigen Mischung der Nefelin- und Leucit- bzw. der Nefelin- und Melilitmoleküle praktisch keine große Bedeutung.

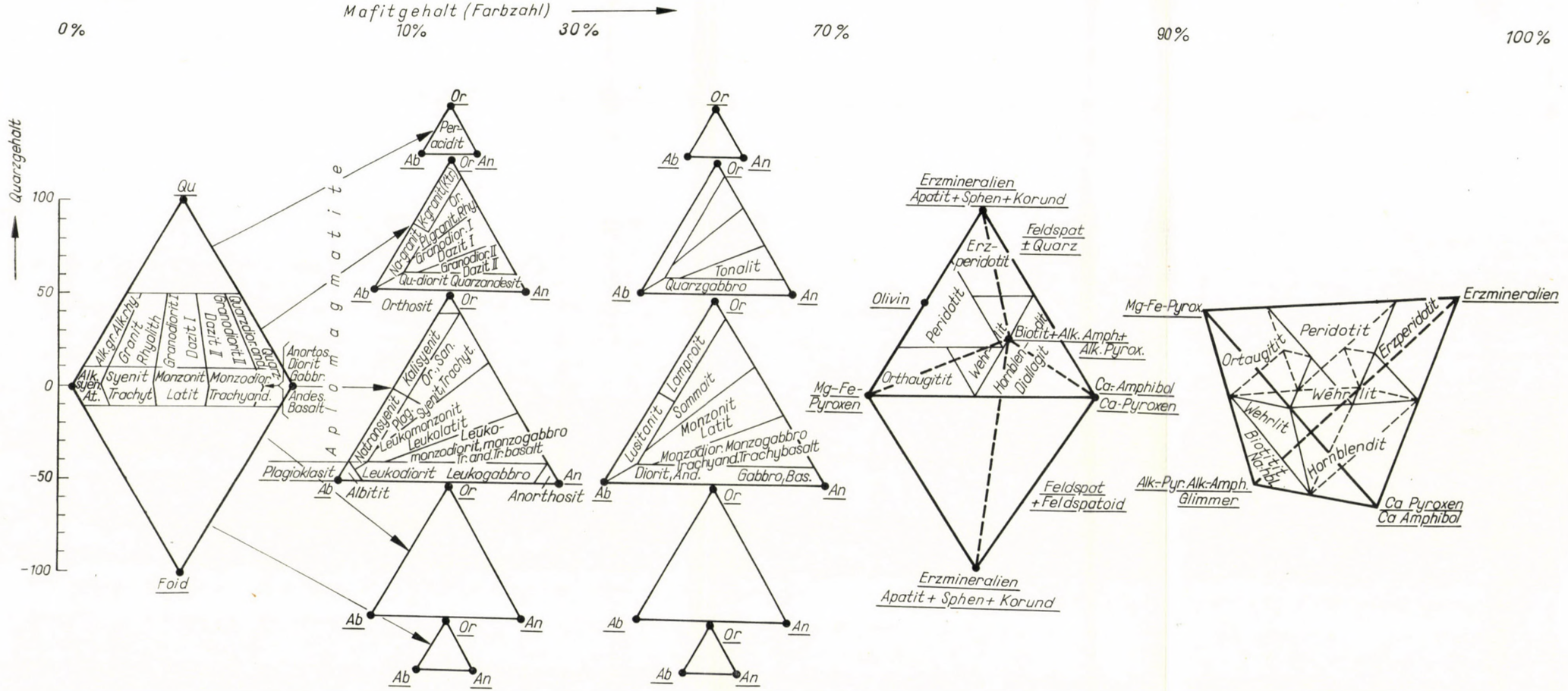
Mafitgehalt (Farbzahl)
0%
10%
30%
70%
90%
100%
Quarzgehalt
100
50
0
-50
-100
Qu
Foid
Alk.gr.Alkchy.
Granit
Rhyolith
Syenit
Trachyt
Granodiorit I
Dazit I
Monzonit
Latit
Granodiorit II
Dazit II
Monzodior.
Trachyand.
Quarzdiorand.
Quarzandesit
Anortos.
Diorit
Gabbr.
Andes.
Basalt
Apomagmatite
Or
Ab
An
Peracidit
Na-granit
K-granit(Kfs)
Alkgranit.Rhy.
Granodior. I
Dazit I
Granodior. II
Dazit II
Qu-diorit
Quarzandesit
Orthosit
Kalisyenit
Or.,San.
Trachyt.
Natronsyenit
Plag.Syenit
Trachyt
Leukomonzonit
Leukolatit
Leuko-
monzodiorit,monzogabbro
Tr.and.Tr.basalt
Plagioklasit
Leukodiorit
Leukogabbro
Anorthosit
Albitit
Lamprait
Lusitanit
Sommait
Monzonit
Latit
Monzodior.Monzogabbro
Trachyand.Trachybasalt
Diorit,And.
Gabbro,Bas.
Tonalit
Quarzgabbro
Erzmineralien
Apatit+Sphen+Korund
Feldspat
±Quarz
Erz-
peridotit
Olivin
Peridotit
Mg-Fe-
Pyroxen
Orthaugitit
Wehrlit
Hornblen-
dit
Diallagit
Biotit+Alk.Amph±
Alk.Pyrox.
Ca-Amphibol
Ca-Pyroxen
Feldspat
+Feldspatoid
Mg-Fe-Pyrox
Ortaugitit
Peridotit
Erzperidotit
Wehrlit
Hornblendit
Alk-Pyr.Alk-Amph.
Glimmer
Ca Pyroxen
Ca Amphibol

Abb. 3

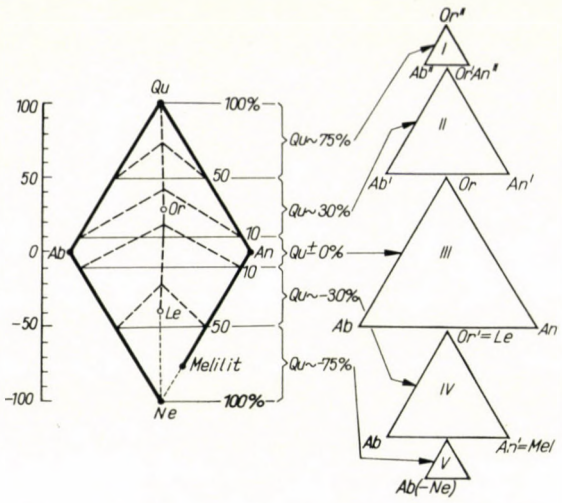

Abb. 2

Abb. 3 siehe unter den Tafeln

Die größte Schwierigkeit der Doppeltetraederdarstellung bildete bisher das Problem der Mafite, die deshalb einfach vollständig vernachlässigt oder auf Kosten der Trennung der K- und Na-Feldspate (RONNER) berücksichtigt wurden. Durch Verdoppelung der obigen 5 Dreieckschnitte kann aber auch dieses Problem in geeigneter Weise gelöst werden (Abb. 3). So bekommt man zwei Hauptserien von Projektionsdreiecken, die der mafitärmeren Gesteine mit weniger als etwa 30%, und der mafitreichen Gesteine mit 30—70% Mafit. Die mafitarme Hauptserie faßt die beiden Serien aplitisch-plagioklasitischer Gesteine mit weniger als etwa 10% Mafit und normaler Magmatite mit 10—30% Mafit zusammen.

Die Unterscheidung dieser beiden Serien kann durch einfache Namensänderung (z. B. Granit und Granitaplit) — ohne besondere Projektion — erfolgen. Die Hauptserie mit 30—70% Mafit braucht keine weitere Absonderung. (Dioritaplit und Gabbroaplit gehören aber zu den anorthosit-gabbroidalen Gesteinen.)*

Die an Mafiten besonders reichen Gesteine (> 70%) gehören zu den abgesondert behandelten Ultrabasiten.

Die quantitative Klassifizierung der Ultrabasite erfolgt (gemäß Abb. 3, rechts) durch eine Tetraederprojektion mit den Polen

* Die Zusammensetzung der Aplite ist meist nicht nur durch eine Verminderung des Mafitgehaltes, sondern oft auch durch die Zunahme des Quarzgehaltes charakterisiert. Deshalb schiebt sich z. B. der Monzonitaplit in das granodioritische Feld.

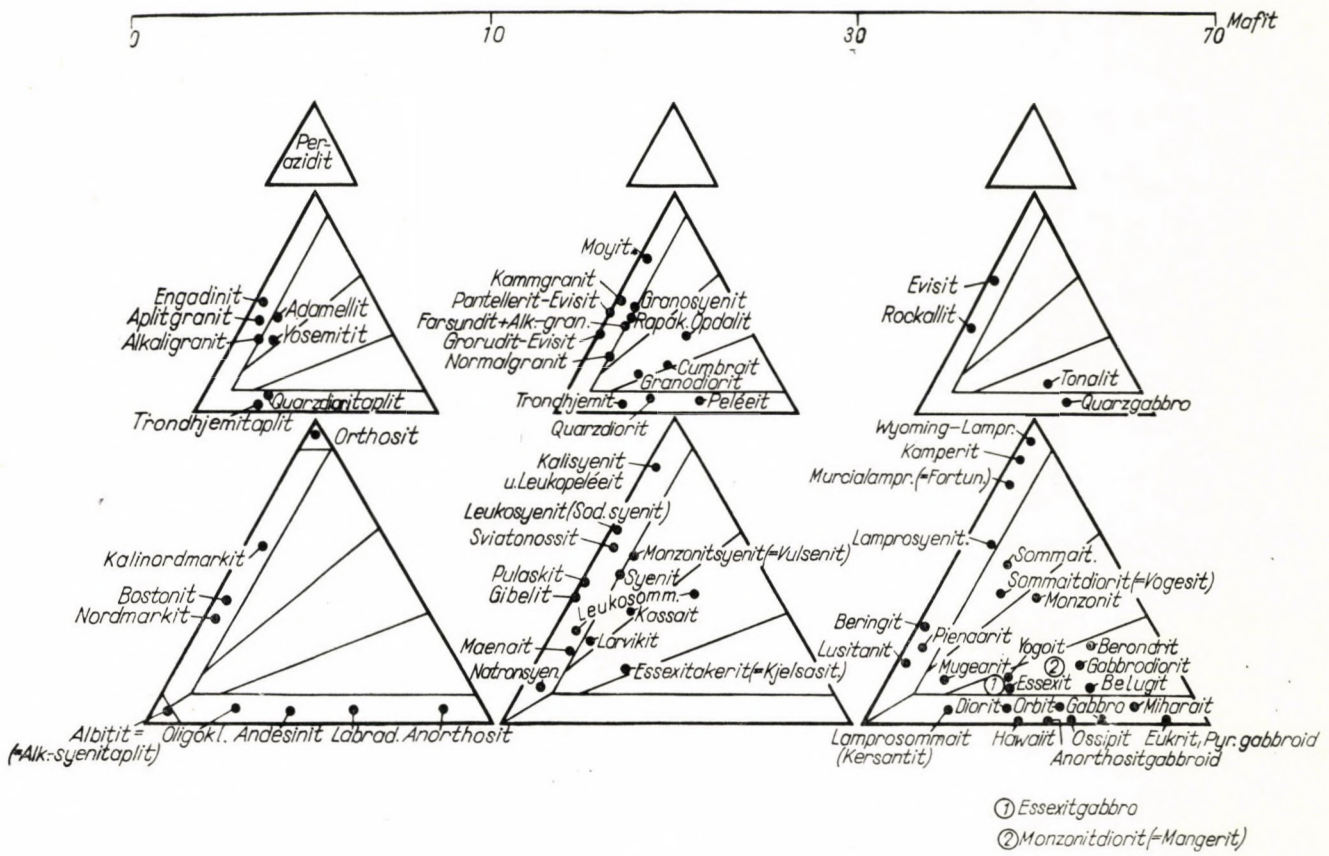
0
10
30
70
Mafit
Per-
azidit
Engadinit
Aplitgranit
Alkaligranit
Adamellit
Yosemitit
Quarzdioritaplit
Trondhjemitaplit
Orthosit
Kalinordmarkit
Bostonit
Nordmarkit
Albitit =
(=Alk-syenitaplit)
Oligokl.
Andesinit
Labrad.
Anorthosit
Moyit
Kammgranit
Pantellerit-Evisit
Farsundit+Alk-gran.
Grorudit-Evisit
Normalgranit
Granosyenit
Rapak. Opdalit
Cumbrait
Granodiorit
Peléeit
Trondhjemit
Quarzdiorit
Kalisyenit
u.Leukopeléeit
Leukosyenit(Sod.syenit)
Sviatonossit
Monzonitsyenit(=Vulsenit)
Pulaskit
Syenit
Gibelit
Leukosomm.
Kossait
Larvikit
Maenait
Natronsyen.
Essexitakerit(=Kjelsasit)
Evisit
Rockallit
Tonalit
Quarzgabbro
Wyoming-Lampr.
Kamperit
Murcialampr.(=Fortun.)
Lamprosyenit.
Sommait.
Sommaitdiorit(=Vogesit)
Monzonit
Beringit
Lusitanit
Pienaarit
Yogoit
Berondrit
Mugearit
Essexit
Gabbrodiorit
Belugit
Diorit
Orbit
Gabbro
Miharait
Lamprosommait
(Kersantit)
Hawaiit
Ossipit
Eukrit, Pyr. gabbroid
Anorthositgabbroid
① Essexitgabbro
② Monzonitdiorit(=Mangerit)

Abb. 4

1. Fe-Mg-Pyroxene
2. Ca-Pyroxene und Ca-Amphibole
3. Alkali-Pyroxene, Alkali-Amphibole und Glimmer
4. Oxydische und sulfidische Erzmineralien.

Olivin wird an der Kante Fe—Mg—Pyroxen-Erzmineralien dargestellt, wobei man mit der Annahme rechnet, daß mit zunehmendem FeO Olivin statt Pyroxen entsteht. Praktisch kristallisiert jedoch bei höheren Oxydationsgraden meist Magnetit oder Hämatit statt Olivin. Dadurch ist in dieser Projektion Olivin nicht immer von der Assoziation Erz + Pyroxen zu unterscheiden.

Die in einem Pol zusammengefaßten verschiedenen Mineralien der Ultrabasiten, z. B. Ca-Pyroxene und Ca-Amphibole bzw. Glimmer und Alkali-Amphibole, Alkali-Pyroxene werden durch besondere Zeichen unterschieden (Abb. 5).

Melilite werden nicht zu den Mafiten, sondern zu den Foiden gerechnet. Karbonatmineralien sind nicht berücksichtigt, da die Karbonatite nicht zu den Orthomagmatiten gehören.

Felsische Mineralien der Ultrabasiten unter 10% werden vernachlässigt. Be einem felsischen Mineralgehalt der Ultrabasiten von 10—30 Volum-%. wird das Doppeltetraeder gebraucht, wodurch Gesteine mit Feldspat ± Quarz und solche mit Feldspat + Feldspathoid abgesondert werden (Abb. 3 und 5).

Somit werden auf Grund der Mafite in sehr einfacher Weise 5 Gruppen unterschieden:

Mafitgehalt $<10\%$: aplitische Gesteine + Plagioklasite
Mafitgehalt 10—30%: gemeine salische Gesteine
Mafitgehalt 30—70%: gemeine femische Gesteine
Mafitgehalt 70—90% } : Ultrabasite
Mafitgehalt über 90% }

Man erhält somit eine Einteilung nach Mafiten mit derselben Abstufungsfeinheit (5 Gruppen) wie die übliche Einteilung nach den Feldspaten.

Die modale Feldspatzusammensetzung wird in die Or, Ab, An Komponenten umgerechnet. Die dadurch gewissermassen beschränkte Modalität erfüllt aber wichtige Aufgaben und ist zur Darstellung des wahren Gesamtcharakters glasführender Phänomagmatite unbedingt nötig. Bei einem extrem modalen System müßte man z. B. ein Gestein mit vorherrschendem andesitischem oder sogar dazitischem Glas, aber mit Labradorit- oder Bytowniteinsprenglingen als Basalt bezeichnen. Ohne obige Trennung der drei Feldspatmolekeln konnte ein Gestein mit verschiedenen zonalen Plagioklaseinsprenglingen und abweichenden Grundmassenplagioklasen eindeutig gar nicht bestimmt werden. Die Berücksichtigung des Glasgehaltes durch Berechnung

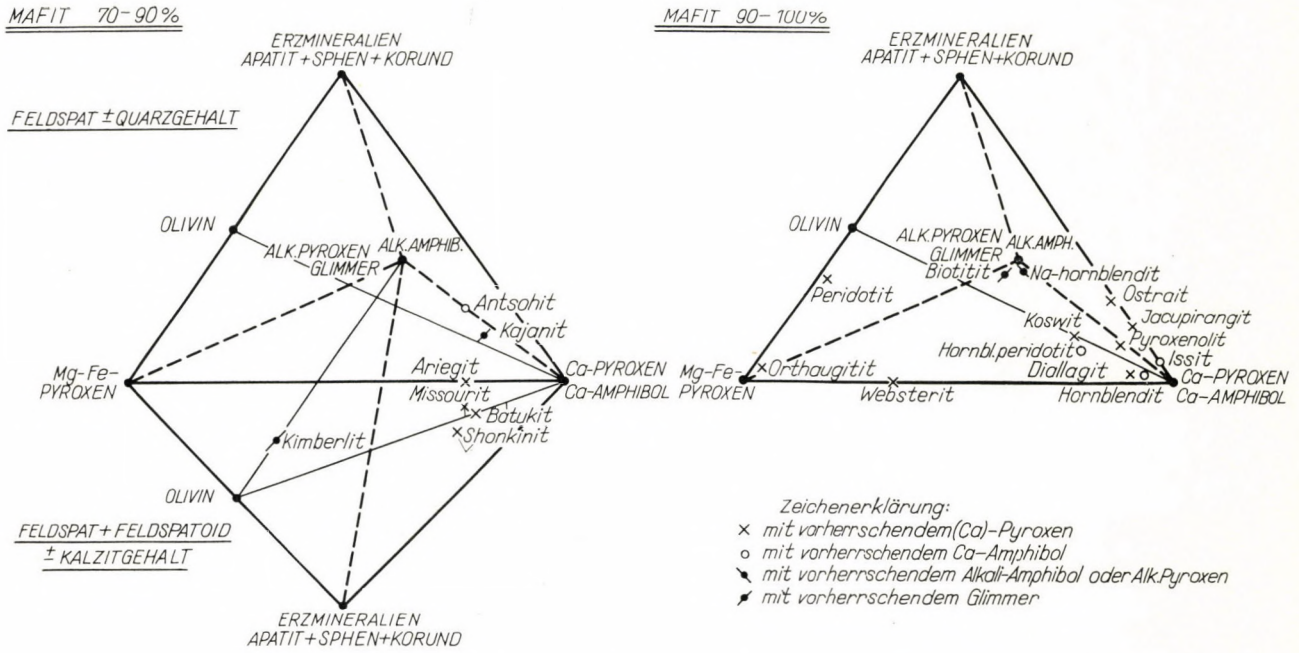
MAFIT 70-90%
ERZMINERALIEN
APATIT+SPHEN+KORUND
FELDSPAT ± QUARZGEHALT
OLIVIN
ALK.PYROXEN
GLIMMER
ALK.AMPHIB.
Antsohit
Kajanit
Mg-Fe-
PYROXEN
Ariegit
Missourit
Ca-PYROXEN
Ca-AMPHIBOL
Batukit
Shonkinit
Kimberlit
OLIVIN
FELDSPAT+FELDSPATOID
± KALZITGEHALT
ERZMINERALIEN
APATIT+SPHEN+KORUND
MAFIT 90-100%
ERZMINERALIEN
APATIT+SPHEN+KORUND
OLIVIN
ALK.PYROXEN
GLIMMER
ALK.AMPH.
Biotitit
Na-hornblendit
Peridotit
Ostrait
Koswit
Jacupirangit
Pyroxenolit
Hornbl.peridotit
Issit
Mg-Fe-
PYROXEN
Orthaugitit
Diallagit
Ca-PYROXEN
Websterit
Hornblendit
Ca-AMPHIBOL
Zeichenerklärung:
× mit vorherrschendem(Ca)-Pyroxen
o mit vorherrschendem Ca-Amphibol
mit vorherrschendem Alkali-Amphibol oder Alk.Pyroxen
mit vorherrschendem Glimmer

Abb. 5

der glasführenden Gesteine ermöglicht aber durch Trennung der drei Feldspatkomponenten eine eindeutige und den entsprechenden Plutoniten parallele Gesteinsbenennung.

Unsere Vorschläge eliminieren auch solche Widersprüche, daß z. B. Gesteine, die an Mafiten ganz arm sind (nach der europäischen Nomenklatur) als Gabbro bezeichnet werden sollen, wenn sie labradoritführend sind. Ähnlich unrichtig wäre es, ein oligoklasreiches Gestein nach dem CIPW-System als Gabbro zu bezeichnen, nur weil es mehr als 37,5% Mafit enthält.* Ein Labradorit- und sogar ein Anorthitandesit, oder ein Andesin- und sogar ein Oligoklasbasalt ist nach unserem System offenbar ein Phänoandesit. Es besteht allerdings die Möglichkeit, die Übergangsglieder zwischen Gabbro und Diorit zwischen etwa 40 und 60% An-Gehalt und ihre Ergußäquivalente (z. B. den Andesitbasalt von Iddings) auch in unserem System unter dem Namen »Gabbrodiorite« (und »Andesitobasalte« oder »Basaltoandesite«) von den reineren Dioriten und Gabbro zu unterscheiden.

Die so erweiterte Projektion der mineralogischen Zusammensetzung ermöglicht gleichzeitig die Darstellung auch der wichtigeren Gesteinssippen bzw. die chemische Absonderung der Orthomagmatiten, was durch die bisherigen Doppeltetraederprojektionen nicht möglich war. Die neue Projektion trennt die kali-, natron-, kalk- und Mg—Fe-betonten Gesteine klar voneinander. Jede Hauptfamilie der Orthomagmatiten bekommt auf diese Weise ihren entsprechenden Platz. Die Absonderung der in dem bisherigen Doppeldreieck ununterscheidbaren gabbroidalen und dioritischen, anorthositischen bis oligoklasitischen, orthositischen und albititischen, normalen und plagioklas-granitischen Kali- und Natronmagmatiten ist somit möglich (Abb. 3).

Als Gesteinsfamiliennamen bedienen wir uns meist nur allgemeingebräuchlicher Termini. Statt Syenodiorit und Syenogabbro bzw. Granogabbro werden die von JOHANNSEN als logischer eingeführten Namen Monzodiorit und Monzogabbro gebraucht. Die entsprechenden »effusiven« Familien werden mit den üblicheren und schon bei RITTMANN in dieser Weise gebrauchten Namen Trachyandesit und Trachybasalt bezeichnet, obgleich die Namen Latoandesit und Latobasalt logischer wären.

Die beiden Abarten der Alkaligranite bzw. Alkalisyenite unterscheiden wir voneinader durch die Namen Kali- und Natrongestein, z. B. Kali- und Natrongranit. Dagegen gebrauchen wir für die beiden Arten der normalen

* Die Trennung des Diorits und Gabbros (bzw. des Andesits und Basalts) erfolgte bekanntlich in verschiedenen Ländern durch verschiedene extreme Standpunkte, z. B. in Europa durch den modalen Plagioklas (Gabbro: An $>$ 50%, Diorit: An $<$ 50%), in den USA nach der Menge der femischen Komponenten der CIPW-Norm (Gabbro: Mafit $>$ 37,5%, Diorit: Mafit $<$ 37,5%). Wir fügen uns mehr dem europäischen Gebrauch, jedoch nicht ohne Berücksichtigung des Mafitgehaltes, da Diorite und Gabbro bei uns sämtlich mehr als 30% Mafit enthalten. Nur unser Quarz- und Leukodiorit bzw. Quarz- und Leukogabbro enthalten 10—30% Mafit.

granitischen und normalen syenitischen Gesteine die Namen Orthoklas- bzw. Plagioklasgestein, z. B. Orthoklas- und Plagioklasgranit, Sanidin- und Plagioklastrachyt. Die Unterscheidung der Orthoklas- von den Plagioklasgraniten ermöglicht es, Gesteine mit sehr geringem An-Gehalt — bis zu einem Verhältnis Oligoklas: Orthoklas ≈ 3 — als Plagioklasgranite zu bezeichnen.

Das Feld mit 40—60% Kalifeldspat (und mehr als 10% Quarz) wurde seit JOHANNSEN (1931) oft als Adamellit-Dellenit, das mit 10—40% Kalifeldspat hingegen als Granodiorit-Rhyodazit bezeichnet. Doch liegt der Granodiorit und Dazit (sogar Rhyodazit und Quarzlatit) im obigen Adamellitfeld, nicht aber der Adamellit und Dellenit selbst. Der ursprüngliche Adamellit von CATHERIN ist nach TRÖGER ein Tonalit, der Adamellit von BRÖGGER ein Normalgranit (Plagioklasgranit Abb. 3) und selbst die Norm des NOCKOLDSschen durchschnittlichen Adamellits und Dellenits sind (Aplo-) Plagioklasgranite. Die Bezeichnung dieses Feldes als Adamellit war also unrichtig. Adamellitisches Magma wird daher von NIGGLI und BURRI zu den granitischen Magmatypen gezählt. Das bisherige Adamellitfeld muß richtig als Granodiorit—Dazit—Feld bezeichnet werden, da außer bei den TRÖGERschen und NIGGLI—BURRIschen Granodioriten selbst die NOCKOLDSsche durchschnittliche Granodiorit-Norm hier liegt. Die Absonderung eines selbständigen Adamellitfeldes ist also zu vermeiden.

Das bisherige Granodioritfeld, in dem übrigens verhältnismäßig wenig Gesteine erscheinen, soll etwa als Kalzigranodiorit bezeichnet werden. Es enthält u. a. den NOCKOLDSschen durchschnittlichen Dazit und den bei ihm damit parallelisierten Tonalit. Der ursprüngliche Tonalit ist jedoch nach TRÖGER ein mafitreiches Gestein, das von dem ursprünglichen Dazit von Siebenbürgen stark abweicht und dem ein besonderes Feld unter den mafitreicheren Gesteinen zukommt (Abb. 3 und 5). Wir parallelisieren daher Dazit mit Granodiorit, entsprechend dem granodioritischen Chemismus des namengebenden Dazits in Siebenbürgen. Rhyodazit ist eine Abart des Dazits.

Im Bereich der subalkalischen Ultrabasite werden 6 Hauptgesteinsfamilien unterschieden (Abb. 3).

1. Orthaugitite (Hypersthenit usw.) mit mehr als 50% Mg—Fe—Pyroxen,

2. Hornblendite und Diallagite mit mehr als 50% Ca-Pyroxen und Ca-Amphibol,

3. Alkalihornblendite, Alkalipyroxenite (insbesondere Na-hornblendite) und Biotitite mit mehr als 50% Alkalihornblende, Alkalipyroxen oder Glimmer,

4. Peridotite mit mehr als 50% Olivin,

5. Erzperidotite mit mehr als 50% Erzmineralien,

6. Wehrlite mit einzeln weniger als 50% der obigen mafitischen Mineralien.

Die Gesteinsfamilie der Wehrlite liegt in der Mitte des Ultrabasit-Tetraeders, wo sie ein verstümmeltes Oktaeder mit einem eingeschnittenen Keil bildet. Die anderen Gesteinsfamilien haben teils vollständige (Biotitite-Alkalihornblendite, Hornblendite-Diallagite, Peridotite), teils schwach verstümmelte tetraedrische Räume (Orthaugitite, Erzperidotite).*

Die neue Projektion ermöglicht auch eine ziemlich empfindliche Darstellung der NIGGLIschen bzw NIGGLI-BURRIschen »Magmentypen« (Abb. 4—5), die bisher wegen der großen Zahl (7) der NIGGLI-Parameter nicht durchführbar schien. Die neue Projektion stellt außer *mg* sämtliche NIGGLI-Parameter dar; *si* verändert sich in vertikaler Richtung, *al* hängt auch von der Lage im Dreieck ab, *c* nimmt in Richtung des An-Pols, *alk* in der des Ab- und Or-Pols, *k* in Richtung des Or-Pols zu, *fm* steigt nach rechts nach den höheren Mafit-Werten hin. Im Bereich der Ultrabasiten nimmt *si* gegen den Pol der Erzmineralien hin ab, *fm* nimmt gegen den Pol der Fe—Mg-Pyroxene hin zu, *al* und *c* nehmen gegen den Pol der Ca-Pyroxene und Ca-Amphibole hin zu und *alk* nimmt gegen den Pol der Alkaliamphibole-Alkalipyroxene-Glimmer zu. Tabl. I zeigt die Verteilung der NIGGLI—BURRIschen Magmentypen und die Zahl der bei TRÖGER besprochenen Gesteinsarten in den einzelnen Feldern der neuen Klassifikation.

Die neue Projektion ermöglicht auch eine annähernde Ableitung bzw. Wiederherstellung des Mineralgehaltes aus dem Projektionspunkt des Gesteins, was bei den bisherigen Projektionen dieser Art ausgeschlossen war.

Die Eintragung der einzelnen Gesteinsanalysen in die Projektion, d. h. die quantitative Bestimmung seiner Familiennamen ist einfach und geschieht auf folgende Weise. Der Quarz- bzw. Feldspatoidgehalt gibt unmittelbar die entsprechenden Dreiecke I—V, der Mafitgehalt die Hauptserie »mafitarm«, »mafitreich« oder »ultrabasisch« an. Die durch die modale Analyse gefundenen Feldspate (z. B. Plagioklas mit gegebenem An-Gehalt, Orthoklas, Anorthoklas, Perthit, Mikroklin, Sanidin) werden in die drei Molekeln Or, Ab, An unter-

* Der Raum Wehrlit-Kvellit besitzt eine selbst im NIGGLI-BURRIschen System nicht spezialisierte chemische Zusammensetzung, die bisher als peridotitisch und jacupirangitisch bezeichnet wurde. Der Chemismus dieses Raumes unterscheidet sich vom peridotitischen durch höhere *c*-Werte und von dem jacupirangitischen durch höhere *fm*- und niedrigere *c*-Werte:

	Jacupirangit	Kvellit	Wehrlit	Peridotit
si	70	44,5	55	60
al	7	11	1,5	5
fm	56	66,5	87,5	90
c	35	17,5	10	4
alk	2	5	1	1

Table 1

Kategorien nach der neuen Klassifizierung	Zahl der Gesteinsarten	Nigglische Hauptmagmentypen	Sporadisch vorkommende Nigglische Magmentypen
(Perazidit)	12	peraziditisch	aplitgranitisch, alkaligranitisch, trondhjemitisch, evisitisch
Aplokaligranit	14	—	aplitgranitisch, engadinitisch, rapakivitisch, alkaligranitisch
Aplonatrongranit	34	aplitgranitisch alkaligranitisch engadinitisch	rapakivitisch, yosemititisch, nordmarkitisch
Aploorthoklasgranit	1	—	normalgranitisch
Aploplagioklasgranit	6	yosemititisch, adamellitisch	granosyenitisch, adamellitisch, leukoquarzdioritisch
Aploadamellit	6	—	yosemititisch, leukoquarzdioritisch, aplitgranitisch, oligoklasitisch
Aplogranodiorit	—	—	—
Aploquarzdiorit	4	trondhjemitaplitisch leukoquarzdioritisch	—
Aplopeleeit	2	—	anorthositisch, peleeitisch
Kaligranit	8	granosyenitisch, moyitisch	aplitgranitisch, alkaligranitisch, kammgranitisch, normalgranitisch, trondhjemitisch, monzosyenitisch
Natrongranit	11	kammgranitisch, pantelleritisch, groruditisch	rapakivitisch, granosyenitisch natronsyenitisch, nordmarkitisch
Orthoklasgranit	2	rapakivitisch	syenitisch
Plagioklasgranit	2	normalgranitisch, farsunditisch	aplitgranitisch
Granodiorit I	16	quarzmonzonitisch, granodioritisch, opdalitisch, cumbraitisch	quarzdioritisch, tonalitisch, normalgranitisch
Granodiorit II	2	—	oligoklasitisch, peleeitisch
Quarzdiorit	6	quarzdioritisch, trondhjemitisch	oligoklasitisch
Peleeit	1	peleeitisch	
Evisit	6	normalevisitisch, rockallitisch	syenitisch, quarzdioritisch
C	—	—	—
D	2	—	tonalitisch
Tonalit	2	tonalitisch	—
Quarzgabbro	2	quarzgabbroid	gabbroid

Kategorien nach der neuen Klassifizierung	Zahl der Gesteins-arten	Nigglische Hauptmagmentypen	Sporadisch vorkommende Nigglische Magmentypen
Orthosit	4	orthositisch	kalinordmarkitisch
Aplokalisyenit	3	kalinordmarkitisch	—
Aplonatronsyenit	4	nordmarkitisch, bostonitisch	pulaskitisch
Albitit	1	albititisch	—
Aploorthoklassyenit	—	—	—
Aploplagioklassyenit	—	—	—
Aploleukomonzonit	2	—	albititisch, oligoklasitisch
Aploleukomonzodiorit	—	—	—
Aploleukomonzogabbro	1	—	theralitgabbroid
Oligoklasit—Anorthosit	5	oligoklasitisch, andesinitisch, labradoritisch, anorthositisch	—
Kalisyenit	12	syenitisch, kali-leukosyenitisch, kaligibelitisch, sviatonossitisch	leukosommaitisch, kalinordmarkitisch, granosyenitisch, murcia-lamproitisch
Natronsyenit	23	natronsyenitisch, pulaskitisch, gibelitisch, maenaitisch	nordmarkitisch, oligoklasitisch, granosyenitisch
Orthoklassyenit	4	monzonitsyenitisch	syenitisch
Plagioklassyenit	9	lårvikitisch, kassaitisch, essexitdioritisch, leukosommaitisch	syenitisch, monzonitfoyaitisch, quarzdioritisch
Leukomonzonit	11	essexitakeritisch	essexitdioritisch, essexitisch, nosykombitisch, monzonitisch, dioritisch
Leukomonzodiorit und Leukomonzogabbro	3	—	dioritisch, monzonitisch, gabbrodioritisch, peleeitisch
Leukodiorit	5	—	oligoklasitisch, essexitdioritisch, monzonitfoyaitisch, albititisch
Leukogabbro	6	—	anorthositisch, anorthositgabbroid
Lamproit	10	kamperit, wyominglamproitisch, murcialamproitisch, lamprosyenitisch	kalinordmarkitisch, sommaitdioritisch
Lusitanit	6	lusitanitisch, beringitisch, (pienaavitisch)	natronlamprosyenitisch, nosykombitisch
Sommait	11	sommaitisch, sommaitdioritisch	lamprosommaitisch, lamprosyenitisch, yogoitisch, theralitgabbroid, theralitisch, nosykombitisch

Kategorien nach der neuen Klassifizierung	Zahl der Gesteinsarten	Niggli'sche Hauptmagmentypen	Sporadisch vorkommende Niggli'sche Magmentypen
Monzonit	21	monzonitisch, mugearitisch	missouritisch, essexitisch, gabbrodioritisch, sommaitdioritisch, monzonit-somaitisch, shonkinitisch, theralitgabbroid, dioritisch
Monzodiorit	8	essexitisch, yogoitisch, essexitgabbroid, monzonitdioritisch	gabbrodioritisch
Monzogabbro	8	gabbrodioritisch, berenditisch, belugitisch	dioritisch, theralitgabbroid, gabbroid
Diorit	21	dioritisch, lamprosommaitisch, hawaiitisch	quarzdiorit, oligoklasit, nosykombitisch, gabbroid, gabbrodioritisch, essexitgabbroid, theralitgabbroid, hornblenditisch
Gabbro	44	gabbroid, ossipitisch, miharaitisch, eukritisch, anorthositgabbroid, pyroxenit-gabbroid, orbitisch	sommaitdioritisch, issitisch, hornblenditisch, peridotitisch, pyroxenolitisch, theralitgabbroid, essexitgabbroid
Hornblendit—Diallagit	8	hornblenditisch, hornblenditperidotitisch, issitisch	
	18	diallagitisch, pyroxenitisch, pyroxenolitisch, jacupirangitisch, ostraitisch, kajanitisch, ariegitisch	
Alkalihornblendit—Biotitit,	4	Na-hornblenditisch, biotitisch, antsohitisch	
Orthaugitit	3	orthaugititisch, websteritisch	
Peridotit	13	peridotitisch	
Erzperidotit	6	erzperidotitisch	
Wehrlit	2	»kvellitisch«	jacupirangitisch, peridotitisch

teilt.* Dadurch wird der Projektionspunkt des Gesteins in dem entsprechenden Dreieck und somit die Gesteinsfamilie bestimmt.

In der Abb. 3 ist neben jedem phaneromerem (»intrusivem«) Familiennamen auch der Name des chemisch entsprechenden »effusiven« Gesteins ein-

* Die Feldspatoiden werden zu den chemisch entsprechenden Feldspaten — also Nefelin zum Albit, Leucit zum Orthoklas, Melilit zum Anorthit — gerechnet. Auf diese Weise fällt z. B. der Leucit führende Sommait in das sommaitische (und nicht in das monzonitische) Feld.

getragen. (Die äquivalenten Paare einiger Gesteine, z. B. die effusiven Ausbildungen der aplitischen und plagioklasitischen Gesteine, sind nicht bekannt.)

Nur durch diese Gesteinsnamenpaare lassen sich auch die verschiedenen Hauptstrukturvarianten einheitlich benennen. Ein »intrusiver« Gesteinsname, wie Granit, Gabbro bedeutet strukturell einerseits eine relativ große Körnung und eine beiläufig isometrische Form der Körner. Die Doppelkurven, die die Korngrößenverteilung nach den längsten und kürzesten mikroskopisch

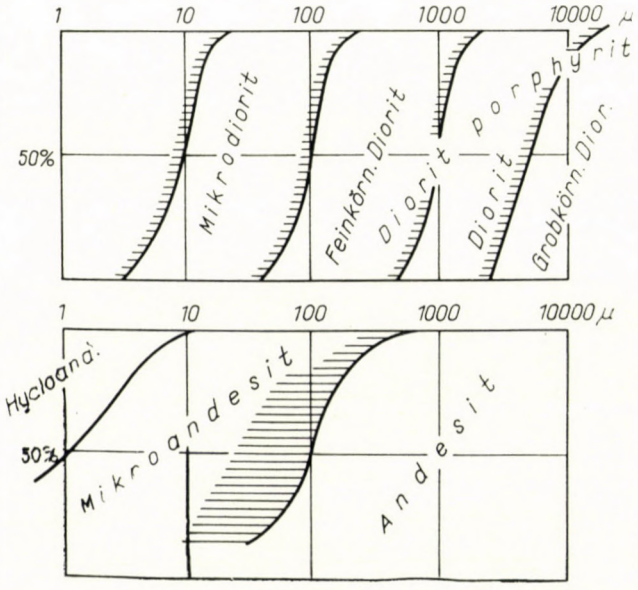

Abb. 6

beobachtbaren Korndurchmessern und somit die Kristallhabitusverhältnisse darstellen, sind hier fast völlig miteinander verschmolzen, können also vernachlässigt werden. In Abb. 6 zeigt die horizontale Strichelung das Gebiet der Korngrößenverteilung zwischen den längeren und kürzeren Korndurchmessern.

Im allgemeinen genügt es, vier Strukturvarianten der normalen (isometrischen und etwa gleichkörnigen) »Intrusiva« zu unterscheiden (Abb. 6):

Grobkörnige »Intrusiva«	mit einem Median über	5	mm
Normale »Intrusiva«	mit einem Median von	5—1	mm
Feinkörnige »Intrusiva«	mit einem Median von	1—0,1	mm
Mikrointrusiva (z. B. »Mikrogranit«)	mit einem Median unter	0,1	mm

Die gewöhnlichen Vulkanitnamen weisen bekanntlich durchschnittlich feinere und zugleich ungleichmäßigere Korngrößen meist mit Absonderung

von 2 Habitusarten der Kristalle auf: größere und mehr isometrische porphyrische Einsprenglinge (»Phänokristalle«) und kleinere, zugleich mehr anisometrische Grundmassengemengeteile. Wir unterscheiden zunächst 3 Varianten der Vulkanite (Abb. 6):

Normale Vulkanite (z. B. Andesit): Median über 0,1 mm
Mikrovulkanite (z. B. Mikroandesit): Median von 0,1—0,001 mm
Hyalovulkanite (z. B. Pechstein, Hyaloandesit): mehr als 50% unter 0,001 mm.

Der Unterschied zwischen einem Mikrodiorit und einem Mikroandesit liegt daher im Grad der Gleichkörnigkeit und im Habitus der Kristalle: der Habitus ist annähernd isometrisch beim Mikrodiorit, anisometrisch beim Mikroandesit. Die großen Durchmesser der Körner sind etwa gleich, und nur die kleineren Durchmesser weichen stärker ab. Bei den »normalen« Vulkaniten fallen die längeren Durchmesser meist mit denjenigen der »feinkörnigen« Plutonite zusammen.

Es sind aber auch solche Magmatite vorhanden, die die ungleichmäßige Korngrößenverteilung der »Effusiva« mit dem meist etwa isometrischen Habitus der »Intrusiva« vereinigen. Diese Gesteine werden mit dem Beinamen Porphyr-Porphyrit bezeichnet.

A QUANTITATIVE CLASSIFICATION OF SUBALKALI ORTHOMAGMATITES

By

D. GIUŞCĂ and E. SZÁDECZKY-KARDOSS

Abstract

The orthomagmatite rock domain — without the ultrabasites — is projected upon five horizontal sections of JOHANNSEN's double tetrahedron, the former being divided, according to the mafic content, into two principal section with 0 to 30, and 30 to 70% mafic content respectively. Then the principal section poor in mafite is divided — without further projection — into two sub-sections: aplitic-plagioclasitic rocks with a mafite content less than 10%, and normal orthomagmatites with a mafite content of 10 to 30%; their distinction in the sub-section of 0—10% mafite is provided by the suffix aplite- (or aplo-). The rocks with more than 70% mafite (i.e. the ultrabasites) are projected in an extra tetrahedron with poles 1. Fe-Mg-pyroxenes, 2. Ca-pyroxenes—Ca-amphiboles, 3. alkali-pyroxenes—alkali-amphiboles—mica, and 4. ore minerals; where olivine is plotted the edge ore-minerals — Fe-Mg-pyroxenes (Fig.2—5). This projection makes a clear distinction between potash-, soda-, lime- and various Mg-Fe-accentuated rocks.

On the basis of the grain-size distribution curves (Fig. 6), the orthomagmatites are divided into 8 groups: *A)* cca. uniformly grained rocks: coarse-grained intrusives (median over 5 mm), normal (5—1 mm), fine-grained (1—0,1 mm) and micro-intrusives (median under 0,1 mm), — and *B)* unevenly grained or vitrous volcanites with 3 subgroups: normal volcanites (median under 1 mm), microvolcanites (0,1—0,001 mm), hyalovolcanites (median under 0,001 mm). The eighth groups contain the porphyr(it)ic rocks with dissimilar grain sizes but with cca. isometric habit.

КОЛИЧЕСТВЕННАЯ КЛАССИФИКАЦИЯ СУБАЛКАЛИЧЕСКИХ ОРТОМАГМАТИТОВ

Д. ДЖУСКА – Э. САДЕЦКИ-КАРДОШ

Р е з ю м е

Область ортомагматических пород — без ультрабазитов — разделяется на пять горизонтальных разреза по двойным тетраэдрам Йогансена. Эти разрезы, в соответствии с содержанием мафитов, разделяются на две главные серии с содержанием мафитов с 0 по 30 и с 30 по 70%. Главная серия, с незначительным содержанием мафитов без дальнейшей проекции разделяется на две нижние серии: аплит-плагиокласовые породы с содержанием мафитов ниже 10% и нормальные ортомагматиты, с содержанием мафитов 10—30%. При этом эти породы начинают отличаться от суффикс-аплитов (или апло) в нижней серии, с содержанием мафитов в 0—10%. Породы с содержанием свыше 70% мафитов (т. е. ультрабазиты) проекцируются в отдельном тетраэдре со следующими полюсами: 1. Fe—Mg пироксены; 2. Ca-пироксены; Ca-роговые обманки; 3. алкалические пироксены, алкалические роговые обманки, слюды и 4. рудные минералы, причем оливин принадлежит к краям минералов Fe—Mg пироксенов (Рис. 2—5). На основе этой проекции возможно точно отличить породы, охарактеризованные калием, натрием, кальцием и прочими минералами Mg—Fe.

На основе кривой распределения величины зернистости (рис. 6) ортомагматиты разделяются на 8 групп: А) Прибл. ровнозернистые — грубозернистые интрузивы (в среднем свыше 5 мм); нормальные (5—1 мм); мелкозернистые (1—0,1 мм); и микроинтрузивы (в среднем ниже 0,1 мм) и Б) Неравномерно-зернистые или стеклосодержащие вулканиты с тремя подразделениями: нормальные вулканиты (в среднем ниже 1 мм); микровулканиты (0,1—0,001 мм) гиаловулканиты (в среднем ниже 0,001 мм). В восьмую группу входят порфировидные породы, с неравномерной зернистостью, но изометрической формой.

ZUR KLASSIFIKATION DER GRANITOIDE UND GABBROIDE AUF EINHEITLICHER MINERALOGISCHER UND CHEMISCHER GRUNDLAGE

Von

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Es wird versucht, die chemische und mineralogische Klassifikation der granitoiden und gabbroidalen Magmatite miteinander zu vereinbaren. Zu diesem Zwecke wird von den drei normativen Feldspaten Or, Ab, An ferner vom Verhältnis Quarz : Kalifeldspat : Plagioklas und durch Berücksichtigung des Colour Index (CI = Menge der normativen farbigen Komponenten) vom Verhältnis Quarz : Alkalifeldspat : Colour Index ausgegangen, wobei als Gesteinsgrenzen auch die statistischen Häufigkeitsminima und -maxima berücksichtigt werden. Die normative Zusammensetzung wird in Katanorm umgerechnet und in Äquivalentprozenten ausgedrückt.

Die Klassifikation der Magmagesteine ist eine Klassifikation nach ihrer Zusammensetzung, die ihrerseits wieder zwei Charakteristika, eine mineralogische und eine chemische hat. Die mannigfaltigen Bedingungen, unter denen sich diese Gesteine gebildet haben, komplizieren die korrelativen Beziehungen zwischen ihrer komponentenreichen chemischen und ihrer phasenreichen mineralischen Zusammensetzung, hauptsächlich durch die Isomorphie und Heteromorphie. Daher hat die von NIGGLI (1931, S.297) vertretene Auffassung, daß »nur eine Doppelklassifikation den Problemen der Petrologie gerecht werden kann«, weithin Verbreitung gefunden. Auf diese Weise geht man bei der Klassifizierung der Magmagesteine praktisch bevorzugt von der mineralischen Zusammensetzung aus, da die sogenannten chemischen Klassifikationen infolge ihrer Loslösung von den realen Gesteinen nur die Bedeutung eines Hilfsmittels haben.

Gegen eine derartige Doppelklassifikation lassen sich zwei Arten von Gründen anführen: 1. Die in stätiger Veränderung begriffene chemische Zusammensetzung ist eine allgemeinere und in genetischer Beziehung wichtigere Eigenschaft der Gesteine als die mineralische, da letztere und die Struktur der Gesteine nur die späteren Etappen ihrer Bildung, d. h. die Kristallisationsperiode, widerspiegeln. Die chemische Zusammensetzung dagegen gibt Anhaltspunkte zur Untersuchung der wesentlicheren petrogenetischen Prozesse der Erdkruste, die mit Bildung und Differenzierung der Magmen zu tun haben. 2. Die chemische Zusammensetzung ist als Klassifikationsmerkmal auch vom praktischen Gesichtspunkt aus vorzuziehen, weil sie in ebensoguter Weise sowohl die holokristallinen als auch die hemikristallinen Gesteine kennzeichnet.

Damit soll natürlich nicht gesagt sein, daß wir uns von der mineralischen Klassifikation zu Gunsten der chemischen lossagen müssen; es soll vielmehr nur anerkannt werden, daß die Synthese zwischen der mineralischen und der chemischen Zusammensetzung der Gesteine eine Daueraufgabe der Petrographie und ihrer Klassifikation ist. Unter diesem Gesichtspunkt werden hier die Fragen der einheitlichen Klassifikation der meistverbreiteten Gesteine — Granitoide und Gabbroide — untersucht.

1. Die Probleme der quantitativen mineralogischen Klassifikation

1.1. Die wichtigsten mineralogischen Parameter, die die Stellung der Granitoide und Gabbroide in der mineralogischen Klassifikation bestimmen, sind die Plagioklase, die Kalifeldspate oder Alkalifeldspate, der Quarz und die farbigen Mineralien. Um in der quantitativen mineralogischen Klassifikation den Unterschied zwischen den kalialkalischen und natronalkalischen Gesteinen ausdrücken zu können, der ein grundlegendes Merkmal der petrochemischen Besonderheiten und des Sippencharakters der Magmagesteine ist, muß der Gegenüberstellung der Natronfeldspate und Kalifeldspate der Vorzug gegeben werden. Durch diese Gegenüberstellung wird ein anderes wichtiges chemisches Charakteristikum der Magmagesteine, nämlich ihr kalkalkalischer Charakter hervorgehoben. Daher muß die quantitative mineralogische Klassifikation das Verhältnis der Plagioklase (einschließlich des Albits) zu den Kalifeldspaten (einschießlich der Anorthoklase) berücksichtigen. Andererseits ist nicht nur der Grenze zwischen Labrador und Andesin, sondern auch der Grenze zwischen Andesin—Oligoklas und Oligoklas—Albit (Pl. mit 25% An) eine Klassifikationsbedeutung beizumessen, insbesondere in bezug auf die Gesteine, deren Feldspate ausschließlich durch Plagioklase vertreten sind (Abb. 3). Albit oder Oligoklas-Albit, die keine Kalifeldspate in Gefolge haben, enthalten manche verhältnismäßig seltene Gesteine (Dreite, Trachyandesite nach DALY, Oligoklasite, Kochalaite, Mugearite etc.).

Dies veranschaulicht das Diagramm über die Zusammensetzung der normativen Feldspate der Granitoide und Gabbroide (Abb. 1). In diesem Diagramm sind die mittleren chemischen Zusammensetzungen der Gesteine nach R. DALY verwendet. Feld 4 entspricht den Gesteinen, deren Feldspate nur durch saure Plagioklase vertreten sind. Es hat eine ganz besondere Lage in Beziehung zu den weiterverbreiteten Gesteinstypen. Das sind die Gesteine von der Gruppe der Plagiogranite und Plagiosyenite und deren effusive Analoga, die häufig unter oben erwähnten speziellen Namen beschrieben werden.

Die Klassifikation von JOHANNSEN berücksichtigt die besondere systematische Bedeutung der sauren Plagioklase, bedient sich aber sehr enger und

künstlicher Grenzen (5, 50 u. 95% An) und einer unnatürlichen Geometrisation, so daß zahlreiche leere Klassifikationszellen entstehen. NIGGLI (1951), der gegen diese Extreme Widerspruch erhebt, überträgt den Albit ganz zu den Kalifeldspaten im Sinne der Klassifikation von ZIRKEL und ROSENBUSCH, womit der auch die zweckmäßige Seite des Vorschlages von JOHANNSEN vernachlässigt. In Wirklichkeit ist die Sonderung der Plagiogranite und Plagiosyenite in dem Klassifikationssystem auf Grund der Zusammensetzung des

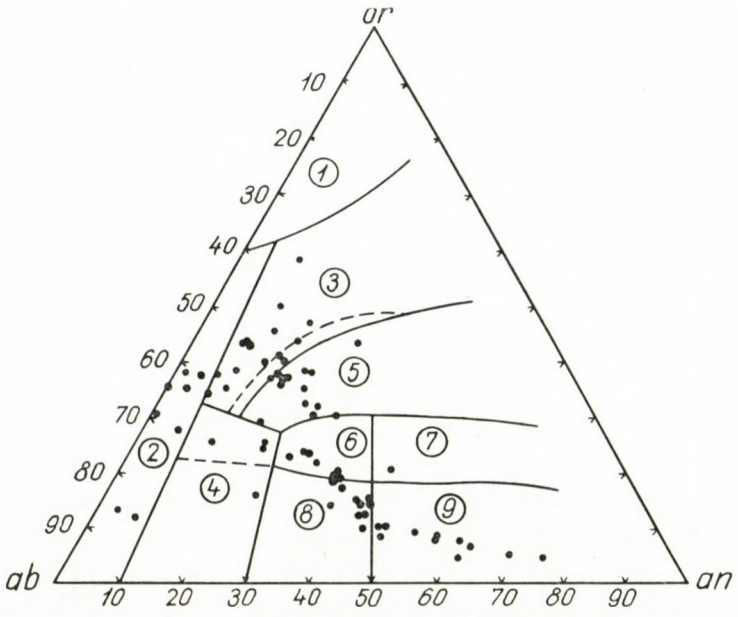

Abb. 1. Die normativen Feldspate der Granitoide und Gabbroide nach den mittleren chemischen Zusammensetzungen von DALY

Plagioklases zweifellos weit mehr gerechtfertigt als die Trennung der Diorite vom Gabbro.

Zweckmäßig wird man anhand der unterschiedlichen Zusammensetzung der Plagioklase die Natronmonzonite (Pl mit An $< 25\%$), die (normalen) Monzonite (Pl mit An 25—50%) und die Kalzi-Monzonite (Pl mit An $> 50\%$), sowie die Natron-Monzodiorite (Pl mit An $< 25\%$) und die (normalen) Monzodiorite (Pl mit An 25—50%) unterscheiden.

1.2. Die quantitativen Verhältnisse zwischen den mineralogischen Parametern der Klassifikation haben recht bedingten Charakter, weil unter den Granitoiden und Gabbroiden alle allmählichen Übergänge vorkommen. Im allgemeinen wird die symmetrische und relativ gleichmäßige Aufteilung des Klassifikationsfelds bevorzugt, wodurch die äußerst kleinen Klassifikations-

gruppen vermieden werden. Nicht mit Unrecht werden jedoch Argumente für eine engere Definition der Gesteinsarten vorgebracht (SOBOLEW 1955, 1959; KERIMOW 1956 u.a.). Sie würde zu einer Zergliederung der größeren Klassifikationsgruppen in einzelne Arten führen und darf nur auf einer einheitlichen Klassifikations- und Nomenklaturgrundlage erfolgen.

1.3. LOEWINSON-LESSING bedient sich für Klassifikationszwecke der statistischen Methode, indem er die Grenzen zwischen den einzelnen Klassifikationsgruppen auf Grund der Minima ihrer Häufigkeiten setzt und den

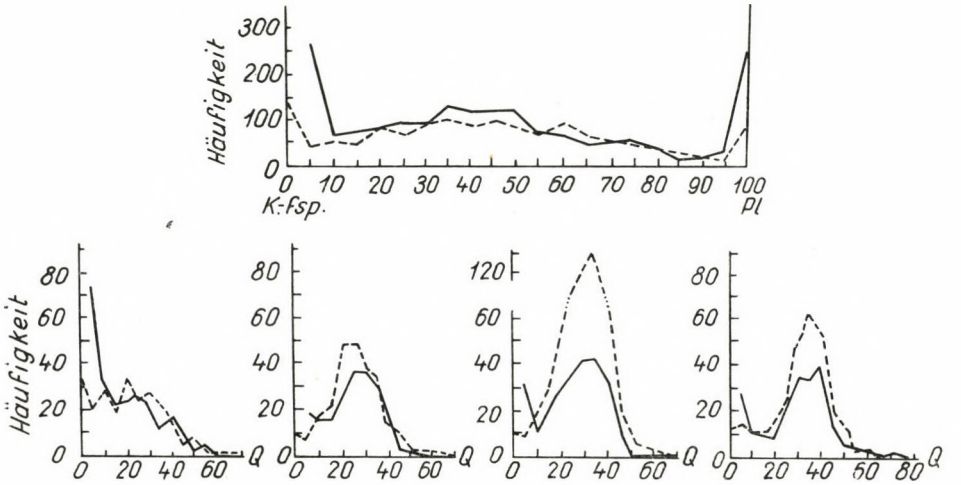

Abb. 2. Die Häufigkeitsverteilungskurven für das Verhältnis Kalifeldspat : Plagioklas und des Quarzes in den Granitoiden der Welt (voll ausgezogen und der Sowjetunion punktiert), nach KUPLETSKI (1953)

Schwerpunkt der Klassifikationsgruppen mit den entsprechenden Maxima in Übereinstimmung bringt. KUPLETSKI (1953) untersucht auf diese Weise das Verhältnis Kalifeldspat : Plagioklas und den Quarzgehalt in den Granitoiden (Abb. 2). Die erste Art von Kurven gibt weder in bezug auf die Gesteine der ganzen Welt, noch in bezug auf die Gesteine auf dem Territorium der Sowjetunion Anlaß zu einer asymmetrischen Unterteilung des Intervalls, wie sie KUPLETSKI in seiner Klassifikation durchgeführt hat. Diese Verteilungskurven sprechen eher für eine symmetrische Aufteilung des Intervalls.

Die Kurven von KUPLETSKI über die Verteilung des Quarzes in den Granitoiden haben im Gegenteil charakteristische Maxima und Minima, deren Inflexpunkte bei ungefähr 7 und 15% Quarz liegen. Diese Werte könnten als ausreichende Kriterien dienen zur Absonderung von drei Reihen nach dem Quarzgehalt: Reihe der quarzfreien Gesteine, Reihe der quarzarmen Gesteine und Reihe der quarzreichen Gesteine.

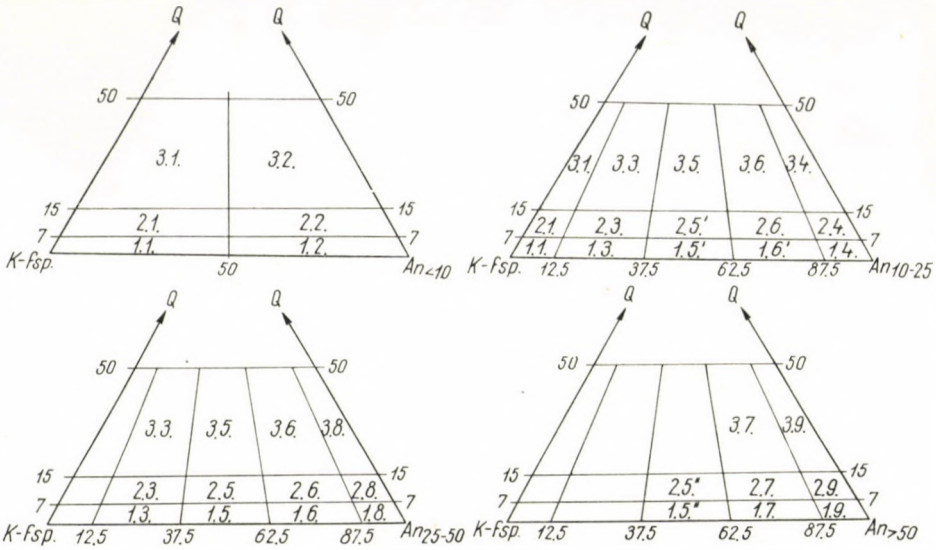

Abb. 3. Die Q : K-feldsp. : Pl-Dreiecke der quantitativen mineralogischen Klassifikation der Granitoiden und Gabbroiden (Erklärungen im Text)

In Abb. 3 liegt ein Entwurf zur Bestimmung der Grenze in den Dreiecken Q : K-feldsp.: Pl der quantitativen mineralogischen Klassifikation der Granitoide und Gabbroide vor, der die obenerwähnten Bemerkungen widerspiegelt. Die entsprechende Nomenklatur ist, wie schon hervorgehoben wurde (IWANOW 1962), die folgende:

1. *Reihe der quarzfreien Gesteine*

1.1. Kalisyenite/Kalitrachyte
1.2. Natronsyenite/Natrontrachyte
1.3. (normale) Syenite/(normale) Trachyte
1.4. Plagiosyenite/Plagiotrachyte
1.5. (normale) Monzonite/(normale) Latite
1.5.' Natron-Monzonite/Natronlatite
1.5." Kalzi-Monzonite/Kalzilatite
1.6. (normale) Monzodiorite/(normale) Latitandesite
1.6.' Natron-Monzodiorite/Natronlatitandesite
1.7. Monzogabbro/Latitobasalt
1.8. Diorite/Andesite
1.9. Gabbro/Basalte

2. *Reihe der quarzarmen Gesteine*

2.1. bis 2.9. Nomenklatur wie unter 1, aber mit der Vorsilbe »Quarz« z. B. 2.3. (normale) Quarzsyenite/(normale) Quarztrachyte; 2.5." Quarzkalzi-Monzonite/Quarzkalzilatite
2.8. Quarzdiorite/Quarzandesite usw.

3. *Reihe der quarzreichen Gesteine*

3.1. Kaligranite/Kalirhyolithe
3.2. Natrongranite/Natronrhyolithe
3.3. (normale) Granite/(normale) Rhyolithe
3.4. Plagiogranite/Plagiorhyolithe
3.5. Adamellite/Dellinite
3.6. Granodiorite/Rhyodazite
3.7. Granogabbro/Rhyobasalte
3.8. Tonalite/Dazite
3.9. Ohne Vertreter

Die quantitativen mineralogischen Klassifikationen bedürfen einer systematischen Anordnung und Neudefinition mehrerer älterer Begriffe, wie dies auch hier oben der Fall ist. Wir werden nicht den Vorschlag in Einzelheiten besprechen, doch soll erwähnt werden, daß »Quarzmonzonite«, »Quarzlatite«, »Quarzdiorite«, »Quarzandesite« usw. nur den Gesteinen der quarzarmen Reihe vorbehalten sind. Für die effusiven Analogen der Monzonite wurde dem Namen »Latitoandesite« vor dem ganz verschieden deutbaren »Trachyandesite« der Vorzug gegeben. Ähnlich ist auch »Latitobasalte« »Trachybasalte« gegenüber bevorzugt.

1.4. In den verschiedenen quantitativen mineralogischen Klassifikationen hat der Begriff »leukokrat-melanokrat« verschiedene Bedeutung. Für die ganze Klassifikation werden allgemeingültige Verhältnisse eingeführt (Johannsen, Jung und Brousse) oder für jede Klassifikationsgruppe im einzelnen »Normaltypen« und entsprechend leukokrate und melanokrate Typen bestimmt (Kupletski, Sobolew, Gendler u. a., bis zu einem gewissen Grade auch Niggli). Das zweite Verfahren konkretisiert in hohem Maße die mineralogische und folglich auch die chemische Charakteristik der Gesteine. Sie ist daher vorzuziehen und muß im Bereich der einzelnen Gesteinsgruppen geprüft werden.

Durch quantitativen Vergleich der normativen farbigen Komponenten (CI: Colour Index) und normativen Alkalifeldspate (AF = Or + Ab) der mittleren chemischen Zusammensetzung der Gesteine aus der Gruppe der Granitoide und Gabbroide nach Daly läßt sich der mittlere Gehalt der farbigen Mineralien in den verschiedenen Klassifikationsgruppen abschätzen

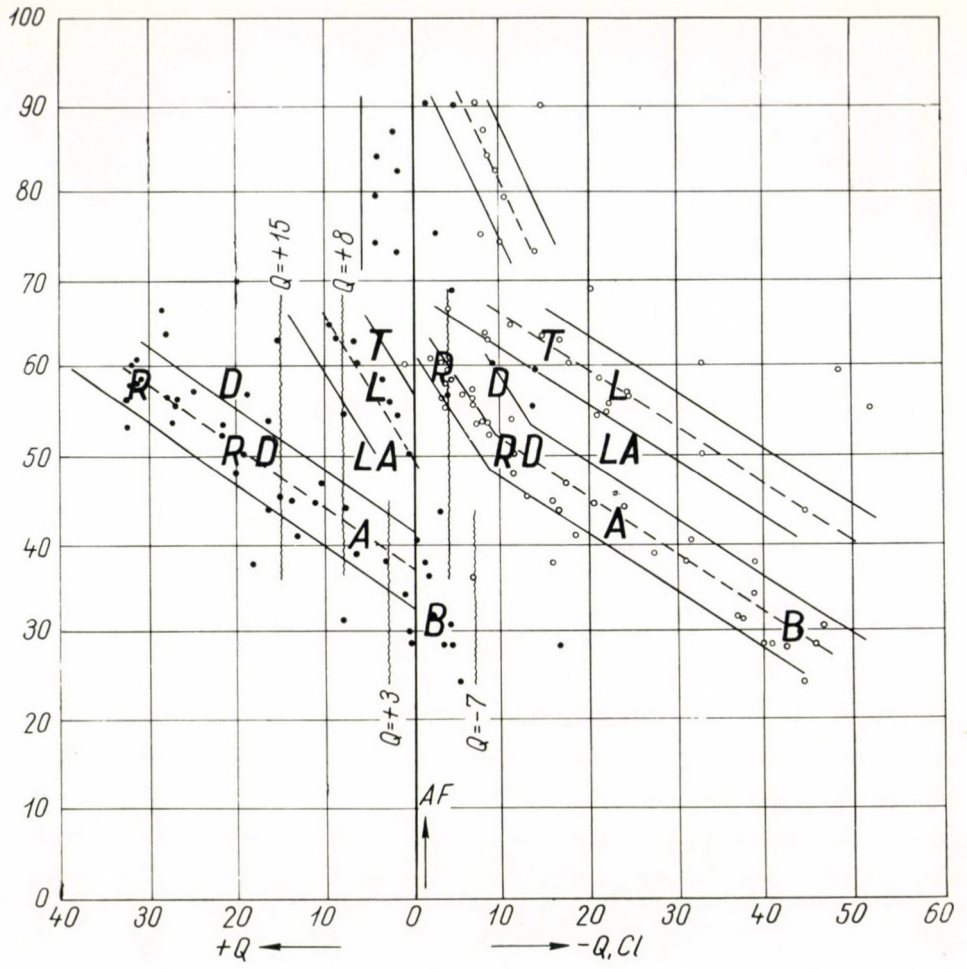

Abb. 4. Q : AF : CI-Diagramm für die Granitoide und die Gabbroide nach den mittleren chemischen Zusammensetzungen von DALY

(Abb. 4). Diese Zusammensetzungen stellen statistische Größen dar und können daher als Normaltypen betrachtet werden. In einen Variationsstreifen fallen die Syenite und Monzonite sowie ihre effusiven Analoga und in einen anderen die Granite, Granodiorite, Diorite und Gabbro mit ihren effusiven Analoga. Diese Korrelation zwischen dem normativen Farbindex und den normativen Alkalifeldspaten bestätigt, daß sich in den Gabbroiden und Granitoiden der Gehalt der farbigen Mineralien in den Normaltypen gesetzmäßig verändert. Eine ungefähre Vorstellung hiervon, in modalem Ausdruck für die verschiedenen Gesteinsgruppen, vermittelt das Diagramm in Abb. 5, das je-

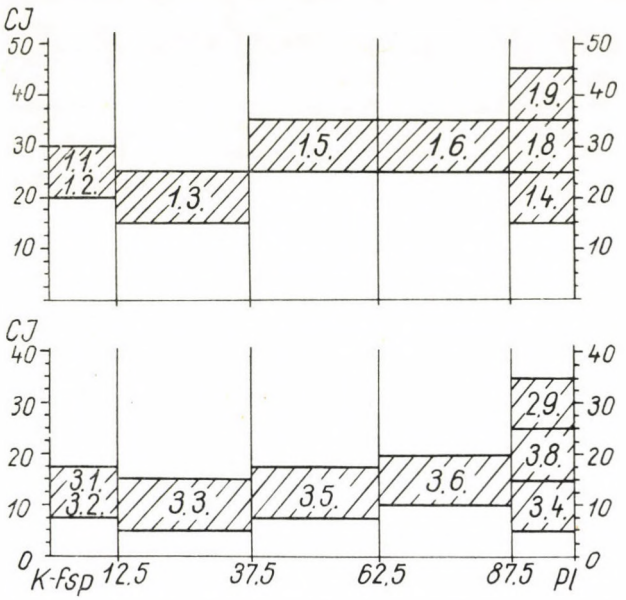

Abb. 5. Die normalen Typen der Granitoide und Gabbroide in bezug auf den Gehalt an farbigen Mineralien (CI = Colour Index = FM + Akc)

doch noch einer weiteren Bearbeitung auf Grund späterer statistischer Untersuchungen bedarf.

2. Die chemische Klassifikationsmethode

muß der chemisch-mineralogischen Klassifikation entsprechen, wenn sie die Voraussetzung für eine einheitliche Klassifizierung der Magmagesteine sowohl nach ihrer mineralogischen als auch nach ihrer chemischen Zusammensetzung schaffen soll. Schon seit Bestehen des CIPW-Systems waren die Bemühungen in dieser Beziehung stets auf die Berechnung der chemischen Zusammensetzung der normativen mineralischen Zusammensetzung der Magmagesteine ausgerichtet. Die Klassifikationen von CIPW, NIGGLI, ZAWARICKI bedienen sich mancher vereinfachter Verhältnisse von gewisser normativer Bedeutung, die sich mehr oder weniger der mineralogischen Klassifikation annähern. Es besteht eine Möglichkeit, die von RITTMANN 1952 ausgenutzt wurde, auf geeigneten Diagrammen Flächen zu begrenzen, die mit der in der beschriebenen Weise korrigierten quantitativen mineralogischen Klassifikation in höchstem Grade übereinstimmen. Ein Versuch in dieser Richtung wird mit folgenden Diagrammen über die normative Zusammensetzung, umgerechnet nach der Katanorm des CIPW, jedoch in Äquivalentprozenten ausgedrückt, unternommen (IWANOW 1961, 1962).

Es wird eine Katanorm bei maximaler Sättigung der Basen mit SiO_2, das heißt bei Bildung von nur normativen Feldspaten (Or, Ab, An), Pyroxenen (En, Hy, Wo) und freiem Quarz (Q), berücksichtigt. Bei SiO_2-untersättigten Gesteinen bildet sich ein normativer Wert — Q, der keine unmittelbare normativ-mineralogische Bedeutung hat, aber in einfachen funktionellen Beziehungen mit den normativen Mengen von Lc, Ne und Ol steht.

Diese normative Zusammensetzung läßt sich durch einfache Rechnungen mit folgenden Werten charakterisieren: $\pm Q$, $AF = Or + Ab$, An, $CI = Py + M + (Hm)$,*

$$M + (Hm);\ n = \frac{Ab}{Ab + Or} \cdot 100 \text{ und } an = \frac{An}{AF + An} \cdot 100;$$

$$f = \frac{\Sigma Fe}{\Sigma Fe + Mg} \cdot 100^{**} \text{ und } wo = \frac{Wo}{Wo + En + Hy} \cdot 100.$$

Auf Grund dieser Werte, die vor allem zur chemischen Klassifizierung der Granitoide und Gabbroide vorgeschlagen wurden, besteht die Möglichkeit, Diagramme zu zeichnen, die sich beim petrochemischen Studium von Gesteinsserien sehr gut bewährt haben (Iwanow 1962, 1963).

2.1. Da die Hauptklassifikationsgruppen in der quantitativen mineralogischen Klassifikation auf Grund der Verhältnisse in der Feldspatgruppe bestimmt werden, erscheint es zweckmäßig, einer derartigen chemischen Klassifikationsmethode das baryzentrische Diagramm der normativen Feldspate zugrundezulegen (Abb. 6). Die realen Feldspate stellen isomorphe Gemische von Endgliedern dar, die sich normativ berechnen lassen. Ihre Zusammensetzung in den Granitoiden und Gabbroiden läßt sich mit hinreichender Genauigkeit den mittleren Werten von Tschirwinski (1953) entnehmen, so wird ein Dreieck der potentiellen Feldspate definiert (Abb. 7). Dieses läßt sich in die gewünschten Verhältnisse aufteilen, die wir nach der von Niggli vorgeschlagenen Achtgliederung durchführen. Die auf diese Weise erhaltenen Felder würden mit recht hoher Genauigkeit die realen Mengen der Feldspate in den Gesteinen in normativen Komponenten ausdrücken, wenn nicht zweierlei Komplikationen vorhanden wären: die Isomorphie im Bereich der Alkalifeldspate und die Heteromorphie zwischen den Feldspaten und manchen femischen Mineralien.

2.2. Der Einfluß der Isomorphie im Bereich der Alkalifeldspate ist aus dem Diagramm in Abb. 8 ersichtlich. Anstatt des Or-Eckpunkts läßt sich die Linie Or-Anor als Basis mancher Dreiecke konstruieren, die Plagioklase mit bestimmter Basizität (An_{20}, An_{30}, oder An_{40}) als gegenüberliegende Eck-

* Die ersten vier Werte sind zu 100 umgerechnet.

** Das Verhältnis $\frac{\Sigma Fe}{\Sigma Fe + Mg}$ ist bevorzugt vor $\frac{Hy}{Hy + En}$, weil es der potentiellen Zusammensetzung der femischen Mineralien besser entspricht.

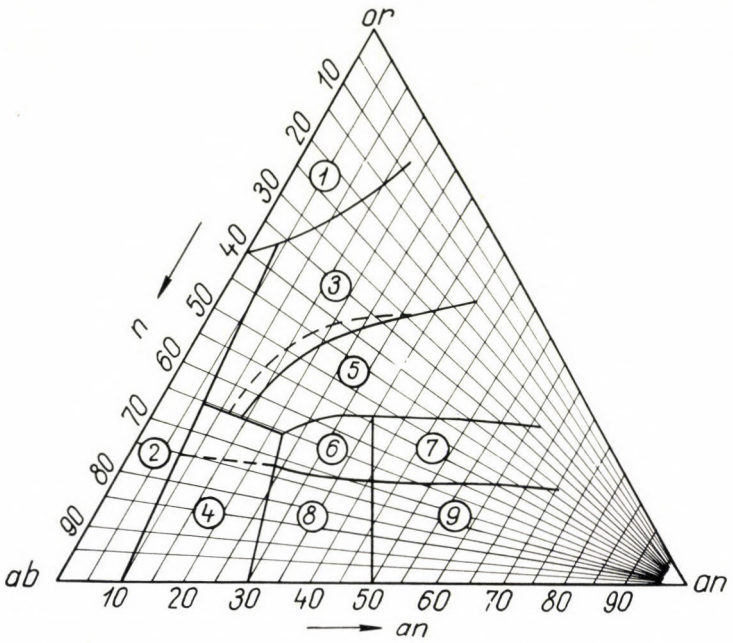

Abb. 6. Die Felder der Familien in der Klassifikation der Granitoide und Gabbroide nach der normativen Zusammensetzung der Feldspate bestimmt

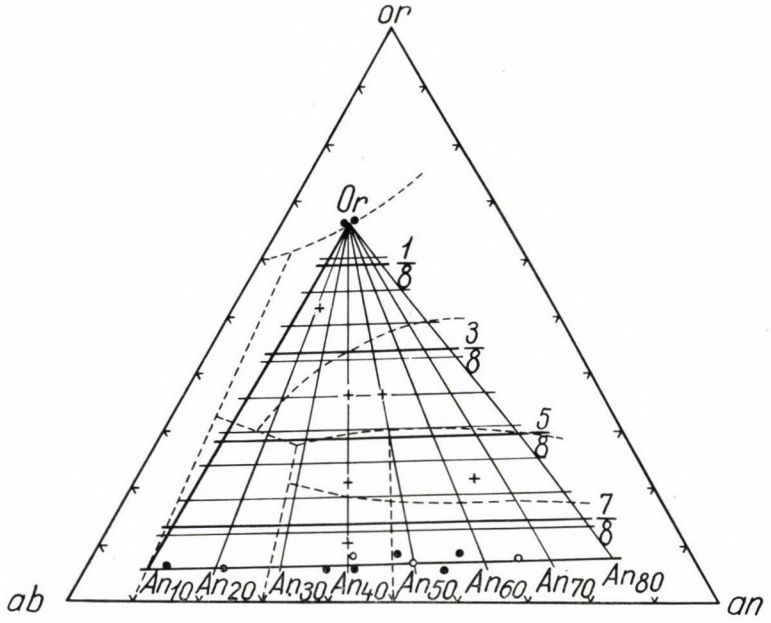

Abb. 7. »Restdreieck« der potentiellen Feldspate der Granitoide und Gabbroide, konstruiert nach Angaben von TSCHIRWINSKI (1953)

punkte haben. Die Grenze $^1/_8$ zwischen den Alkaligraniten und Graniten wird durch das Auftreten von Anorthoklasen unerheblich beeinflußt. Die größte Bedeutung hat die Isomorphie der Alkalifeldspate im Gebiet der Grenze $^3/_8$ zwischen den Graniten und Adamelliten und zwischen den Syeniten und Monzoniten, weshalb sie die Konstruktionslinie tangieren muß. Da die Quarzgesteine saurere Plagioklase (vornehmlich Oligoklase) enthalten als die quarzfreien (vornehmlich Andesine), müßte die Grenze hier für die einen und die anderen eigentlich verschieden gezogen werden (Abb. 7).

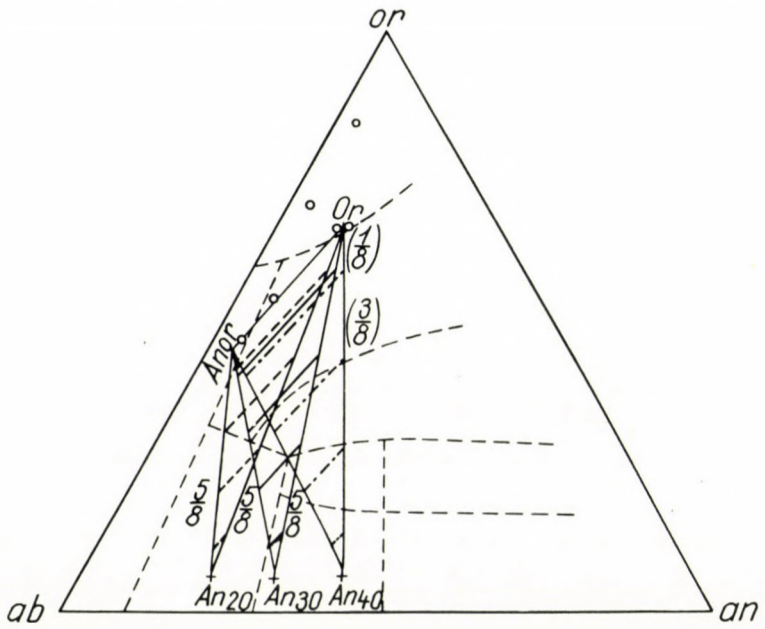

Abb. 8. »Restdreiecke« der potentiellen Feldspate der Granitoiden und Gabbroiden bei Berücksichtigung der isomorphen Mischbarkeit im Gebiet der Alkalifeldspate. Nach Angaben von TSCHIRWINSKI (1953)

2.3. In den einzelnen femischen Mineralien sind die relativen Mengen der normativen Feldspate recht verschieden (Abb. 9). Die Summe der Feldspatkomponenten zeigt folgende Werte (in Äquivalentprozenten): rhombische Pyroxene 8—10%, Augite 18—20%, Amphibole etwa 40%, Biotite 70—80%. Darum spielen Biotit und Amphibol in der Heteromorphie mit den Feldspaten die wesentlichste Rolle. Die heteromorphe Vertretung der Plagioklase durch Amphibol ist nicht imstande, die Lage des Projektionspunktes im Diagramm der normativen Feldspate erheblich zu verändern, da ihre Komponenten mit ungefähr denselben Verhältnissen auftreten. Die Amphibole bewirken meist schwache Translationen zum Eckpunkt An.

Die Biotite der Granitoide und Gabbroide zeigen eine recht gute Gruppierung nach der Zusammensetzung der normativen Feldspate. 10 Äquivalentprozent Biotit enthalten durchschnittlich ca. 5 Äquivalentprozent Or, ca. 1 Äquivalentprozent Ab und ca. 15 Äquivalentprozent An. Da die Monzonite und Monzodiorite die höchsten Biotitmengen (normalerweise nicht über 15—20%) enthalten, ist in Abb. 9 die Verschiebung des Projektionspunktes bei einem derartigen Biotitgehalt in das Diagramm eingetragen. Obwohl diese

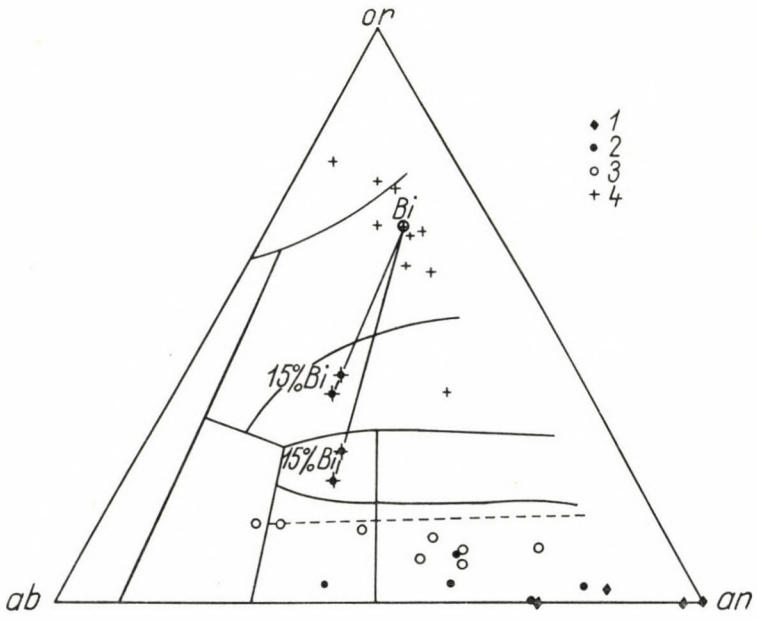

Abb. 9. Die Zusammensetzung der normativen Feldspate der einzelnen femischen Mineralien nach Angaben von TSCHIRWINSKI (1953)
1. Rombische Pyroxene, 2. Augite, 3. Amphybole und 4. Biotite

Verschiebung erheblich ist, führt sie dennoch die mittlere chemische Zusammensetzung der Gruppe nicht aus dem entsprechenden Klassifikationsfeld heraus, was darauf hinweist, daß das Or : Ab : An-Diagramm für einen adäquaten Vergleich der mineralogischen mit der chemischen Klassifikation anwendbar ist.

Auf Grund der empirischen Angaben und um den Einfluß des Biotits in den Biotitandesiten zum Ausdruck zu bringen, erscheint es zweckmäßig, die obere Grenze der Diorit- und Gabbrofelder auf dem Diagramm etwas höher zu ziehen als es ihr konstruktiver Platz erfordern würde, wenn man den Biotiteinfluß unberücksichtigt ließe.

2.4. Das auf diese Weise konstruierte Diagramm findet eine gute Bestätigung durch die Projektionspunkte der chemischen Zusammensetzungen,

deren Modalenzusammensetzungen bekannt sind. Es wurden (IWANOW 1962) die Angaben nach JOHANNSEN und TRÖGER sowie die mittleren Zusammensetzungen nach DALY (Abb. 1) verwendet. Manche der mittleren Zusammensetzungen von DALY, z. B. für die Diorite und Andesite liegen an der Grenze zwischen dem sechsten und achten Feld. Das zeigt, daß sie nicht die für die Diorite und Andesite typische mittlere mineralische Zusammensetzung wider-

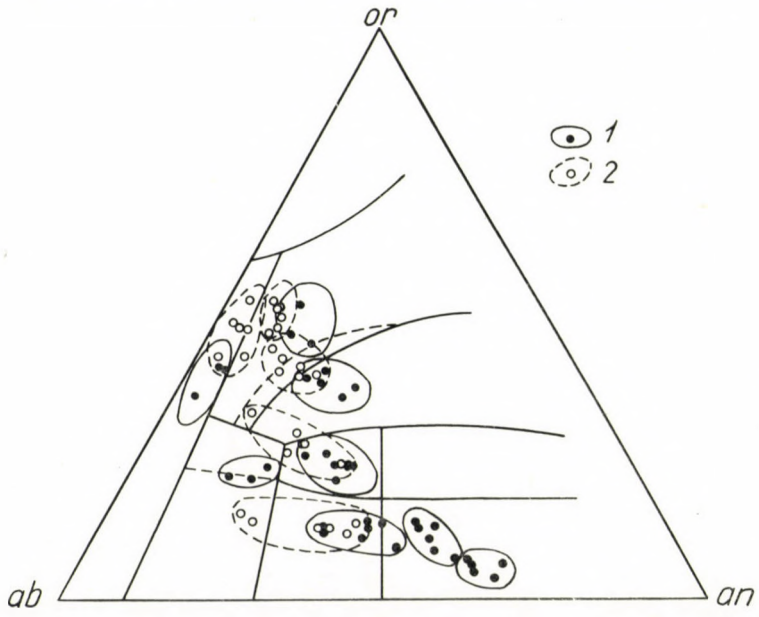

Abb. 10. Die Lage der mittleren chemischen Zusammensetzungen der Granitoide und Gabbroiden nach NOCKOLDS (1954) im Klassifikationsdiagramm nach Abb. 6
1. Gesteinsgruppen der quarzfreien Reihe, 2. Gesteinsgruppen der quarzreichen Reihe. Im Feld 4' Akerite und Mugearite. (Weitere Erklärungen im Text)

spiegeln, was deutlich aus ihrer Gegenüberstellung mit den neuen mittleren Werten für die Granitoide und Gabbroide, berechnet von NOCHOLDS (1954), hervorgeht (Abb. 10), die sehr gut in die entsprechenden Felder passen. Man bemerkt eine Verschiebung der Amphiboldiorite zum Gabbrofeld hin, wie oben vorausgesehen.

Die Muskovit-Biotit- und die Biotit-Tonalite geraten in das Feld der Plagiogranite, was offensichtlich nicht auf den Einfluß des femischen Minerals, sondern auf die sehr saure Zusammensetzung des Plagioklases zurückzuführen ist. Diese Gesteine liegen ziemlich abgesondert von den typischen Tonaliten, was, wie eingangs dargelegt, dazu berechtigt, sie als Plagiogranite zu bestimmen. Eine solche Lage nehmen auch die oligoklasen Tonalite und die Oligoklasite aus dem Kompendium von JOHANNSEN ein.

Von den von NOCKOLDS beschriebenen Granodioriten fallen die Muskovit-Biotit-Granodiorite in das Feld der Granite. Von ihnen kann vermutet werden, daß sie im Zusammenhang mit der Bildung des Muskovits eine sekundäre Anreicherung mit Alkalien erfahren haben. Das von den Adamelliten NOCKOLDS' eingenommene Feld ist entsprechend dem saureren Charakter des Plagioklases in Richtung der Alkalianreicherung verschoben.

2.5. Auf Grund der normativen Mengen des freien Quarzes, der Summe der farbigen Mineralien und der Summe der Alkalifeldspate in der an Siliciumdioxyd gesättigten Katanorm wird ein Q : AF : CI-Diagramm konstruiert (Abb. 4). Die gesetzmäßige Lage der mittleren Zusammensetzung der Granitoide und Gabbroide in dem Diagramm gestattet mit ziemlicher Sicherheit, das Gestein mit der fraglichen chemischen Zusammensetzung der quarzfreien, der quarzarmen oder der quarzreichen Reihe zuzuordnen und wie bereits erwähnt, ihren leukratischen, normalen oder melanokratischen Typ zu bestimmen.

2.6. Die Genauigkeit der Bestimmungen nach den Diagrammen für Gesteine, deren Zusammensetzung sich den mittleren Werten der Klassifikationseinheiten nähert, ist zufriedenstellend. Die Bestimmungen der Gesteine halten sich in den Grenzen der Klassifikationsgruppe, die ihrer mineralischen Zusammensetzung entspricht.

Die Abarten, die eine Zwischenstelle einnehmen, können auch in die benachbarte Klassifikationsgruppe geraten.

Die hier dargelegte chemische Klassifikationsmethode vermag die ihr zugrunde liegende quantitative Klassifikation nicht zu ersetzen. Sie hat aber gegenüber den anderen chemischen Klassifikationen folgende Vorzüge: 1. die hemikristallinen Gesteine lassen sich auf quantitativer mineralogischer Grundlage bestimmen. 2. Die durch die Isomorphie und Heteromorphie verschleierte potentielle mineralische Zusammensetzung des untersuchten Gesteins wird in Normativwerten verglichen. 3. Die Abweichungen der untersuchten Zusammensetzung von der in der Klassifikation angegebenen mittleren Zusammensetzung lassen sich mit derselben Nomenklatur beschreiben, ohne daß es notwendig wird, neue Begriffe einzuführen. 4. Das vorgeschlagene Diagramm ermöglicht den petrochemischen Vergleich einer großen Zahl von Gesteinsanalysen.

Die Anwendung der Katanorm auf eine derartig dynamischen Weise vereinigt die Vorzüge der vergleichenden petrochemischen Methoden mit dem definiten Charakter der quantitativen mineralogischen Klassifikationen und bietet eine Grundlage für deren chemische Konkretisierung.

3. Folgerungen

Abschließend ist hervorzuheben, daß die hier betrachteten Fragen von der Klassifikation der Granitoide und Gabbroide nicht auf die Notwendigkeit

hinweisen, neue Prinzipien in die Klassifikation einzuführen, sondern die Notwendigkeit einer Präzisierung und Vereinheitlichung der schon seit langem geltenden Klassifikationskriterien durch internationale Übereinkommen unterstreicht.

Die quantitative mineralogische Klassifikation bedarf einer konventionalen Festlegung der Grenzen der einzelnen Klassifikationsgruppen und der Nomenklatur. Notwendig sind einige kleinere Änderungen, die es gestatten, die wichtigeren chemischen Besonderheiten der Gesteine durch ihre mineralische Zusammensetzung deutlicher zu kennzeichnen.

Notwendig sind ferner statistische Untersuchungen über die Verbreitung der Magmagesteine von verschiedener Zusammensetzung zwecks Feststellung:

1. der mittleren chemischen Zusammensetzungen von quantitativ mineralogisch bestimmten Gesteinsgruppen, 2. der Variationen in der chemischen Zusammensetzung unter dem Einfluß der Menge, Isomorphie und Heteromorphie der gesteinbildenden Mineralien.

Auf dieser Grundlage ließe sich die einheitliche mineralogisch-chemische Klassifikation der Magmagesteine verbessern und hinsichtlich des akzessorischen und Kleinelementengehalts weiterentwickeln.

ON THE CLASSIFICATION OF GRANITOIDS AND GABBROIDS ON A UNIFORM MINERALOGICAL AND CHEMICAL BASIS

By

R. Ivanov

Abstract

This is an attempt to unite the chemical and the mineralogical classification of granitoid and gabbroid magmatites. For this purpose the author starts with from the three normative felspars Or, Ab, An, the relation between quartz: potash-felspar: plagioclase and, the consideration of the Colour Index (CI = quantity of normative colour components), from the relation quartz/alkali felspar/ Colour Index. Besides this, also the statistic frequency minima and maxima are considered as rock boundaries. The normative composition is reduced to katanorms and expressed in equivalent percentage.

КЛАССИФИКАЦИЯ ГРАНИТОИДОВ И ГАББРОИДОВ НА ОСНОВЕ ЕДИНЫХ МИНЕРАЛОГИЧЕСКИХ И ХИМИЧЕСКИХ ПРИНЦИПОВ

Р. ИВАНОВ

Резюме

Автор стремился к определению химической и минералогической классификации гранитоидов и габброидальных магматитов. В этих целях он исходил из трех нормативных полевых шпатов Or, Ab, An, далее из соотношения кварц калиевый полевой шпат : плагиоклас, с учетом индекса цветов (CI = количество нормативных компонентов цвета) и соотношения кварц : щелочный полевой шпат : индекс цветов. При этом в качестве предела пород учитывались и статистический минимум и максимум распространенности. Нормативный состав был пересчитан в катанормы и выражался в эквивалентных процентах.

THE ROLE OF POTASSIUM METASOMATISM ON VOLCANIC ROCK GENESIS IN THE WESTERN MÁTRA MOUNTAINS

By

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As indicated by the mineralogical and petrographical features of the volcanics, the Western Mátra Mountains underwent prolonged and variegated endometavolcanic processes. As a result a considerable volume of andesitogenic potassic trachyte came into existence. On the basis of the mineralogical composition two principal processes can be distinguished: *a)* potash metasomatism and *b)* hydrothermal silicification. Potash metasomatism, a higher-temperature process, resulted in the formation of three species of alkali silicates, namely sanidine-adularia, glauconite-celadonite and zeolites. During the second lower-temperature period many types of SiO_2 were formed: quartz and cavity-filling types of chalcedony.

The O_{Fe} values of endometamagmatic potash trachyte and similar adularia-bearing rocks are higher than those of hemiorthomagmatic and orthomagmatic rocks. It is partly owing to this feature that the formation of sanidine and adularia on the one hand and that of glauconite on the other, both requiring high O_{Fe} values, is connected with this type of rock.

In the formation of extensive endometavolcanics in the Western Mátra Mountains, the moisture-bearing sedimentary base played a decisive role in agreement with the findings of SZÁDECZKY-KARDOSS (1958—1960).

Water which liberated and transported potassium might have been derived from the sedimentary beds and it then traversed the tectonically fissured zones of the volcanic series. Thus the major part of the water could be regarded as of transvaporizatory origin.

Most of the area delimited by the crescent-shaped ridge linking the Tót-hegyes with Mount Hidegkút, with the Nyikom and the Muzsla is covered by various metavolcanites which exhibit hypomagmatic influences, mostly by andesitogenic potash trachytes resulting from extensive potassium metasomatism and hydrothermal processes (KUBOVICS 1959, 1962). The extent and intensity of the alteration were determined in the first place by the principal structural lines that govern also the direction of the migration of solutions and by the mineral constitution and the structure peculiar to the rocks.

The oldest formation outcropping in the area is a Tortonian plagioclase rhyolite tuff uplifted along a fault of E—W strike. The overlying middle volcanic series consists of a variegated complex of andesites and andesite tuffs (bronzitic pyroxene andesite, augite-base andesite, vacuolar andesite and micro-andesite). Alteration is most intense on the plagioclase rhyolite tuff and particulary on the vacuolar andesite.

The first trachyte outcrop in Hungary (Mounts Gyepű and Kánya in the Tokaj Mountains) became known as a result of a study by M. PÁLFY (1927).

Its detailed volcanologic study, the establishment of its mineralogical-petrographical character and of its place in the system of the Intra-Carpathian volcanic wreath as well as the denomination "potash trachyte" are due to SZÉKY-FUX and HERRMANN (1951).

The varieties of trachyte, formerly held to be orthomagmatic, were revealed by recent studies to be of a metasomatic origin. The problem of potash metasomatism lately entered the foreground of interest owing to the extensive petrographic alterations and ore mineralizations connected with the process (KORZHINSKY 1953, SOBOLEV-KOSTIUK et al. 1955, GIUȘCĂ D. 1957, RADULESCU 1958, FIALA—PÁCAL 1957—59, SCHERF—SZÉKY-FUX 1959, VARGA-MÁTHÉ 1961, NEMECZ—VARJU 1963, SZÉKY-FUX 1964). The conditions of the origin of the varied species of hemiortho-hypo and metamagmatic rocks of high potash content have been clarified by SZÁDECZKY-KARDOSS (1958, 1959). The latter author stated the rocks of highly varied composition known as pseudorhyolites, pseudotrachytes, potash trachytes, etc. to be the results of "prometasomatism" ("Breimetasomatose"). He pointed out the gradual transition between prometasomatism and metamagmatic potassium metasomatism, subsequently proved also by the investigations of SCHERF and SZÉKY-FUX in the Telkibánya area (1959).

At present three minor areas of high potash abundance are known in the Mátra Mountains: 1. The metasomatized sericitic middle rhyolite tuff of the Aranybányafolyás (KISS 1958), 2. The potash trachyte of Feketető (VARGA 1959) and 3. The andesitogenic potash silicotrachyte of Mount Hidegkút and the Aranyosbérc (KUBOVICS 1959). Also to this set belong the "decomposed" and silicified "andesites" of Mount Világos (VIDACS 1962) and the alkali-rich volcanics of some levels of the Gyöngyösoroszi-II boring (KUBOVICS 1963).

The predominant secondary potash felspar of the andesitogenic potash trachytes known from literature are adularia and, to a lesser extent, sanidine. In rhyolite tuffs and bentonitized tuffs alkali-rich zeolites (heulandite—clinoptylolite) may locally be fairly abundant besides adularia (NEMECZ-VARJU 1961, RAVASZ-BARANYAI—NAGY-MELLES 1964). The chemical and mineralogical composition of the Mátra Mountains metasomatites is highly varied owing to the diversity of their origin (Table I). Although their detailed mineralogical and petrographic study is as yet far from being complete, the available data suffice to state that the alkali silicates most abundantly represented are illite-sericite (Gyöngyösoroszi-II boring, Aranybányafolyás) and also adularia and sanidine.

The mineralogical and chemical composition of the potash trachyte of Mount Hidegkút closely resembles that of the Feketető facies described by Gy. VARGA.

Table 1

	1 %	2 %	3 %	4 %	5 %	6 %	7 %	8 %	9 %
SiO_2	65.25	65.20	65.93	68.75	57.76	61.57	67.92	66.24	66,22
TiO_2	0.70	0.94	0.66	0.71	0.84	0.90	0.16	0.22	0.37
Al_2O_3	14.23	14.96	16 54	13.94	19.29	14.99	15.39	16.90	15.58
Fe_2O_3	5.04	3.22	3.35	3.27	6.41	6.64	3.18	2.28	5.29
FeO	0.33	0.22	0.13	0.58	0.13	0.25	0.14	0.32	0.33
MnO	0.00	0.00	0.03	0.03	trace	0.02	0.11	0.06	0.01
MgO	0.27	2.03	0.25	0.06	0.46	0.96	trace	0.21	0.17
CaO	0.71	0.40	1.41	1.18	0.39	0.58	0.61	0.82	0.27
Na_2O	3.56	0.48	2.25	4.36	2.62	0.97	0.57	1.43	0.39
K_2O	6.07	9.67	6.00	2.38	7.82	11.07	11.27	9.06	10.02
H_2O^-	0.83	0.47	1.45	1.20	0.93	0.66	0.22	1.59	—
H_2O^+	2.08	2.82	1.97	3.16	3.31		0.65	0.53	—
CO_2	0.19	0.00	—	—	—	1.13	trace	trace	—
P_2O_5	0.71	0.10	0.15	0.20	trace	trace	0.06	0.15	0.07
L. o. i.	—	—	—	—	—	—	—		1.05
Total	99.97	100.51	100.12	99.82	99.96	99.74	100.28	99.81	99.77
O_{Fe}- value	30.55	29.27	51.54	11.28	98.62	55.12	46.86	14.25	32.06

1. Andesitogenic potash silicotrahyte. Western Mátra Mountains, Mount Hidegkút. Analysts, B. Simó and Mrs. B. Kovács.

2. Potash trachyte, Central Mátra Mountains, Feketető (E of Galyatető Peak). Analyzed at the State Geological Institute (after Gy. Varga).

3. "Decomposed andesite." Western Mátra Mountains, south of the Világos. Analyst, G. Csajághy. (After A. Vidacs).

4. Siliceous andesite, Western Mátra Mountains. 750 metres ESE of Világos peak. Analyst V. Tolnay. (After A. Vidacs.)

5. "Hydroandesite." Central Mátra Mountains. Aranybányafolyás. Analyst, Mrs. K. Guzy. (After J. Kiss.)

6. Alkali trachyte, Tokaj Mountains, Mount Kánya. Analyst, M. Földvári-Vogl. (After V. Széky-Fux and M. Herrmann.)

7. Andesitogenic potash trachyte, Tokaj Mountains, Nagyszáva Peak (487 metres). Analyst, V. Tolnay. (After K. Varga-Máthé.)

8. Andesitogenic potash trachyte, Tokaj Mountains, Torpa valley. Analyst, V. Tolnay. (After K. Varga-Máthé.)

9. Adularized "quartziferous andesite". Baia Mare, Murgău ridge. Analyst, K. Emszt. (After Pálfy and Giuşcă.)

Metasomatism and the hydrothermal influence mainly resulted in the formation of three species of alkali silicate, sanidine-adularia, glauconite-celadonite and zeolites, besides the widespread varieties of SiO_2.

No significant change took place in the alkali content of the plagioclase rhyolite tuff. In comparison to the silicification (quartzitization) of varied intensity, the biotite is relatively fresh. The plagioclase and the pumice, however, turned into sanidine or adularia and partly into zeolites. Metasomatism accompanied by a similar adularization has been observed by SOBOLEV-KOSTIUK et al. on the rhyolite tuff of Beregovo.

The mineralogical and chemical composition of the andesitogene potash silicotrachyte is highly variable depending on its state of alteration. The principal constituents besides quartz and other varieties of SiO_2, all of rather variable abundance, are potash felspar, mainly sanidine, lesser amounts of adularia and glauconite-celadonite.

Sanidine, adularia and orthoclase can be distinguished according to SPENCER (1930, 1937) in the first place by their optic orientation, which depends among other things on temperature. In artificially heated sanidine the angle of the optic axes may vary within broad limits, but in natural crystals it is always small, not much exceeding 0° and never beyond 30°. Besides temperature, the optic properties are also influenced by the chemical composition, as proved by the zonal sanidine of Or_{77} to Or_{60} composition described by K. J. HSU (1954). The experimental data are thus seen to be modified considerably by the natural conditions. At lower temperatures the 2V angle hardly varies at all. Consequently, the optic axis angle and particularly the position of the axial plane yields but an approximate information as to the temperature of origin. The incertitude is increased by the circumstance that the liberation of Na — that is, a durable metamagmatic influence — results in the alteration of sanidine into adularia of a great axis angle.

This fact is also reflected in studies by SPENCER (1937), CHAISSON (1950) and BAMBAUER—LAVES (1960) who stated that the transition between sanidine and adularia is a continuous one even from the optical point of view.

Adularia exists in a number of varieties whose origin is governed by the prevailing conditions. ALLING (1923), BARTH (1928, 1929) and KÖHLER (1948) distinguished optically monoclinic and triclinic adularia. CHAISSON found the smaller grains of 1 to 2 millimetre size to be wholly monoclinic as regards their optical features. He observed that the angle of extinction of crystals larger than 3 millimetres decreases gradually towards the interior of the grain and drew the conclusion that at room temperature the originally monoclinic mineral gradually turns into a more stable triclinic modification. In consequence the "mixed" monoclinic-triclinic adularia of variable angle of extinction could develop also within one and the same grain. As the optical properties are sub-

stantially influenced by the K : Na ratio, it seems highly probable that the transition of sanidine to adularia and the further transition within the adularia grains is a consequence of a gradual infiltration of K and expulsion of Na ions. This is probably why the process sets in at points of larger specific surface, at the acute angle subtended by the (110) prism faces.

The secondary porphyric potash felspar of the andesitogenic potash trachyte around Mount Hidegkút proved on the basis of its $2V = 0—25°$ value to be mostly low-temperature sanidine. Phenocrystalline adularia is scarce, existing only in the more intensely altered varieties, but it forms locally in considerable quantities in the course of the alterationof the matrix and particularly of the acidic pumice (plagioclase rhyolite tuff).

The twin lamellation and zonality of the original felspar grains was wiped out in the course of metasomatism and the neutral to basic plagioclase turned in its entirety into inhomogeneous sanidine of spotty extinction (plate 1, Fig. 1). As the optic axis angle generally increases with decreasing inhomogeneity, it seems very probable that under increased metasomatism the sanidine gradually changes into adularia by the expulsion of Na. Besides the decrease in temperature this is the main reason why almost Na-free adularia of $2V = 30$ to $56°$ frequently becomes predominant in the immediate vicinity of certain mineralized areas (Kremnica, Gutin Mountains, as well as the Tokaj Mountains penetrated by numerous hydrotherms).

In the quartz andesite of Baia Mare Murgău Ridge, first described by PÁLFY (1915), GIUȘCĂ observed the direct adularization of plagioclase. This latter author found that — as contrary to the minute monoclinic rhomboid crystals of the matrix — the adularia formed out of plagioclase is triclinic with, however, a set of optical properties, particularly $2V\ \alpha$, reminding of sanidine. On the other hand, M. BÖHMER (1961) found the potash felspar of 20 to $30°$ axis angle of the metasomatic potash trachyte of Kremnica — whose axial plane deviated slightly from (010) — to be sanidine. All this goes to prove that the delimitation of sanidine from adularia is not unequivocal and that the problem is far from being satisfactorily resolved.

The transitions between the chemical composition and the optical properties of the two species of potash felspar being so gradual, it seems to be justified to distinguish them on the basis of the optical axis angle as suggested by BÖHMER.

The nature, direction etc. of potash felspar metasomatism may be influenced besides the temperature relations and the physico-chemical properties of the ascending solutions also by the chemical composition of the original plagioclase. The differences between the andesitogenic potash trachytes of Baia Mare, Telkibánya and the Mátra Mountains, reflected also by the chemical composition of the rock, particularly the K : Na ratio, may in part also be due to this circumstance.

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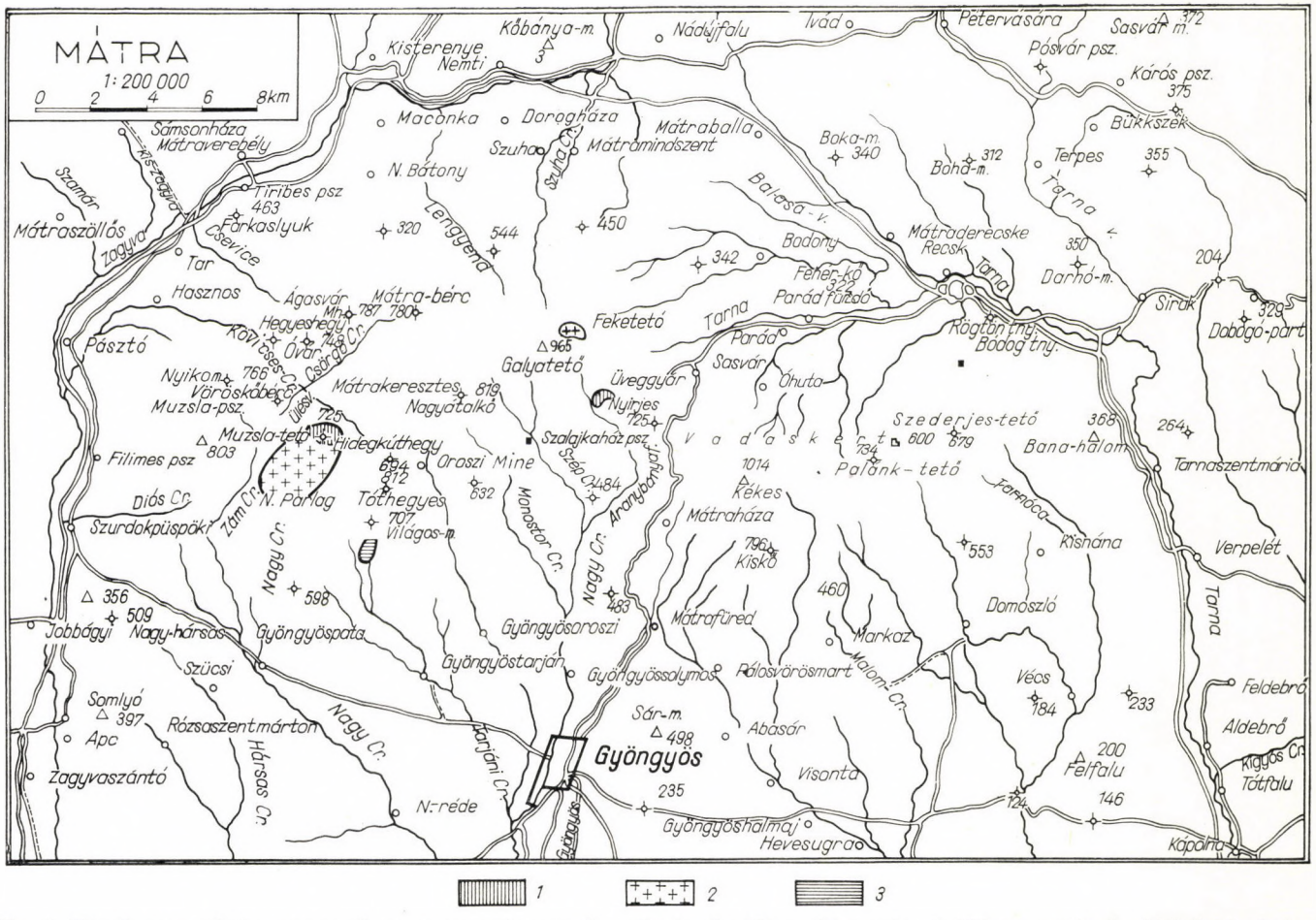


Fig. 1. Sketch map of the extent of metamagmatic potash rocks in the Mátra Mountains *1.* "Metasomatized middle" plagioclase rhyolite tuff. — *2.* Andesitogenic potash trachyte. — *3.* Alkali-rich "silicic" and "altered" andesite

The delimitation of glauconite from celadonite was rather ill-defined for a fairly long period. Celadonite was generally considered to be an Al-free variety of glauconite, but this principle was not applied consequentially. Thus for instance the celadonite derived from the melaphyre of Zwickau-Neuschönburg and described by SCHÜLLER and WOHLMANN completely lacks Al, whereas the mineral from Vesuvius contains 10.90 percent alumina. According to HENDRICKS and ROSS (1941) celadonite contains more Mg and Si than glauconite. The ionic number of Mg — as against .35 to .45, very exceptionally . 26 to .52, in glauconite — is mostly between .61 and .71 with extremes of .52 and 1.05. A similar deviation is seen in the case of Si. The Si ionic number ranging from 3.44 to 3.84 in glauconite with a mean of 3.65 is modified in celadonite to 3.85 to 4.0 with a mean of 3.91, that is, the substitution within the tetrahedron is subordinate. According to YODER and EUGSTER (1955) the two minerals can be distinguished by the R^{3+} in sixfold and fourfold coordination on the one hand and by the number of exchangeable ions on the other: these features also depend in the end on the chemical composition, first of all on the abundance of tri- and bivalent cations (Fe^{3+}, Al^{3+}, Fe^{2+}, Mg^{2+}). As the decreasing abundance of R^{3+} is necessarily accompanied by an increase in the abundance of the bivalent metals, particularly Mg, and Fe^{2+}, as well as of Si, this subdivision essentially confirms HENDRICKS's and ROSS's idea. On this basis the member from the deepest level of the hypomagmatic glauconite series of the Ágasvár area, whose composition is $[K_{0.8}(Mg_{0.5}Fe^{++}_{0.3}Fe^{+++}_{0.8}Al_{0.4})(Al_{0.15}Si_{3.85}O_{10})(OH)_2]$ is still slightly celadonitic, whereas $[(K_{0.5}Na_{0.1}Ca_{0.2})(Mg_{0.4}Fe^{++}_{0.2}Fe^{+++}_{0.8}Al_{0.53})(Al_{0.37}Si_{3.63}O_{10})(OH)_2]$ in the middle and upper horizon of the lower andesite and $[(K_{0.31}Na_{0.10}Ca_{0.2})(Mg_{0.38}Mn_{0.02}Fe^{++}_{0.06}Fe^{+++}_{0.83}Al_{0.41}Ti_{0.02})(Al_{0.4}Si_{3.6}O_{10})(OH)_2]$ in the vacuolar and microandesite are definitely and even typically glauconitic (Fig 2.). As according to SCHÜLLER and WOHLMANN glauconite and celadonite constitute an isomorphic series of continuously variable mixing ratio, the two minerals cannot be distinguished except in the case of an extreme chemical composition. YODER and EUGSTER (1955) established a continuous transition between illite, sericite and glauconite. The glauconite of the middle, vacuolar andesite falls, however, outside the limits of the diagram presented by the above-named authors. This fact, together with microscopic observation, indicates a close relationship, both chemical and genetical, between glauconite and the montmorillonite minerals, particularly saponite. This relationship is convincingly demonstrated among others also by BURST's (1958) decomposition and transition sequence (Fig. 3). The possibility of substitution between the individual elements is, then, rather diversified in the above mineral group and this is why the distinction of the two minerals is not unequivocal even on the basis of the YODER-EUGSTER diagram.

The glauconite-celadonite abundant in the middle volcanic series cannot be considered of a uniquely endometavolcanic origin. The cavities of the

completely fresh vacuolar andesite, mostly channels of 1 to 8 millimetre cross section, carry vivid green glauconite crystals perpendicular to the walls of the cavities, sitting upon a generally colourless clay mineral of higher birefringence radially-fibrous saponite (Plate I, Figs. 2 to 4). This circumstance indicates a gradual cooling, continuous crystallization. A likewise nodular-radial glauconite is observed in the so-called microandesite overlying the vacuolar andesite,

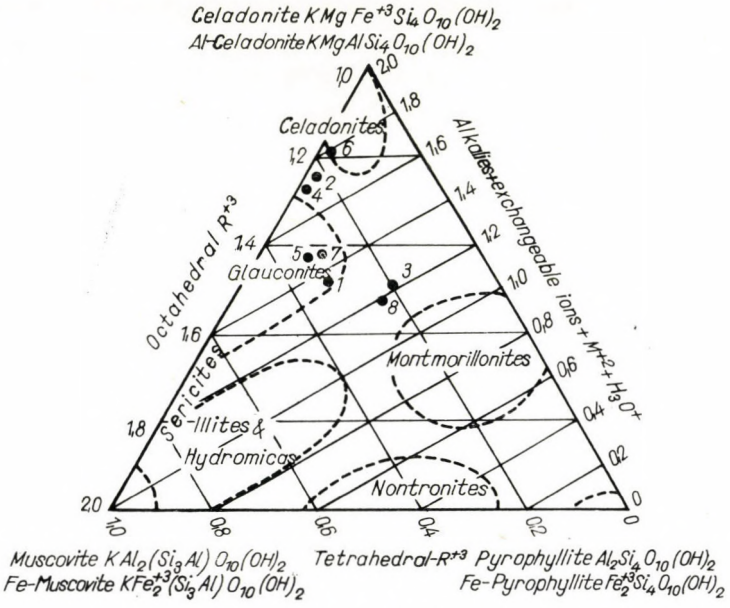


Fig. 2. The position of glauconite types derived from diverse rocks in the YODER — EUGSTER diagram

1. Glauconite from phosphatite, Balaton Highland, Pécsely. — *2.* Glauconite-celadonite from a sedimentary carbonatic manganese ore. Bakony Mountains, Urkút. — *3.* Glauconite from marl. Bakony Mountains, Bakonybél. — *4.* Glauconite from Oligocene (Rupelian) clay marl, Bükk Mountains, Eger. — *5.* Glauconite from Eocene marl and limestone, Tokod. — *6.* Celadonite from andesite (lower level), Western Mátra Mountains, Ágasvár. — *7.* Glauconite from andesite (middle level), Western Mátra Mountains, Ágasvár. — *8.* Glauconite from vacuolar andesite (middle andesite group), Western Mátra Mountains, Hegyes Peak—Ülés Valley

characterized by the appearance in places of felspar in the low-temperature assemblage (Plate II, Figs. 1—2). On the basis of the above-mentioned observations the first formation of saponite-glauconite can be regarded as the direct continuation of the main crystallization, due to the water vapour of transvaporizatory origin that also produced the cavities in the andesite. Also the clay minerals (mostly nontronite) of the vacuolar andesite, fairly widespread in the Western Mátra Mountains, are of a largely hypo, probably also of hypometamagmatic origin but the process of crystallization presumably came to an end before the formation of glauconite.

Part of the material filling the vacuoles of the andesitogenic potash trachyte around Mount Hidegkút can be regarded as the product of a purely endometamagmatic process, although presumably directly connected with the above-outlined phenomena. The first product, radial, light to yellowish green glauconite perpendicular to the walls of the cavities, locally alternates with quartz — a sign of rhythmic precipitation. The mineral assemblage of the inner part of the channels, however, mostly consists of diverse varieties of SiO_2, predominantly quartz, occasionally calcite. The abundance of glauconite is highly variable; occasionally it fills out completely the channels of a few millimetres cross section, elsewhere forming a lining of a few tens of microns on the channel wall. The fibrous radial aggregates and nodules, due to replacement

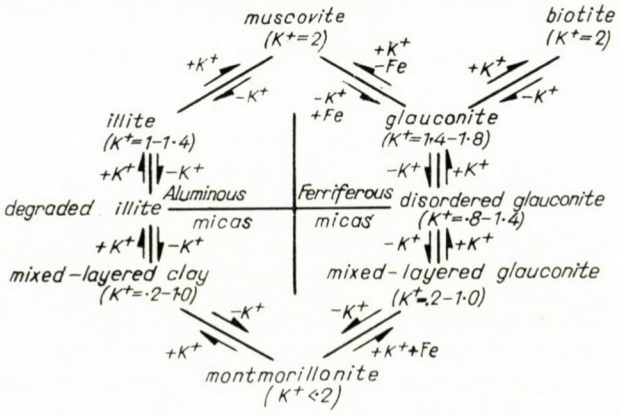


Fig. 3. Relationships between glauconite, mica and the clay minerals after J. F. BURST (1958)

processes, more frequent in the marginal parts of the andesite, consist of substantially larger crystals of ten to a hundred millimetres length (Plate II. Figs. 3—4), indicating a higher temperature or longer duration of the crystallization process in the matrix. The colour, pleochroism and general habit differ somewhat from those of the hypomagmatic glauconite of Ágasvár and Hegyes Peak, owing presumably to differences in composition, first of all to a lower iron and alkali content and a higher concentration of aluminum, suggesting a facies closer to the clay minerals. The substances that make it up, particularly the magnesium and iron, probably derive from the dark silicates of the deeper levels, decomposed in the acid, reducing solutions prevailing there.

The gradual alteration, limonitization-goethitization of glauconite, also observed fairly frequently, is a process that can be ascribed at least in part to an exometamagmatic oxidizing influence. In the rocks of the outcrops the previous presence of glauconite is frequently revealed by the limonite content of the cavities and channels only.

Simultaneously with, as well as subsequently to, potash metasomatism, an intense silicification took place that resulted in the formation of considerable

amounts of quartz in the matrix and in the cavities (Plate III, Fig. 1). The second and third generation of SiO_2 consists almost entirely of low-temperature concentric-layered or radially fibrous chalcedony, partly reddish jasper and cristobalite (Plate III, Figs. 2—4, Plate IV, Figs. 1—3). The most intense silicification (chalcedonization) is observed on the southern rim of the potash trachyte (Jánosvára-Nagyparlag). It is presumably with this latter that the "lode-like", locally pyrite-rich quartzite of the Aranyosbérc is connected. The quartzite carries traces of Pb, Zn and Cu and some 10 grams per metric ton of gold.

Around the potash trachyte, particularly in the andesite adjacent to the silicified zone, various degrees of decomposition can be observed depending on the original structure of the rock and on the physico-chemical properties of the ascending solutions. In the thin-platy microandesite covering most of the surrounding area the most frequent process of decomposition is the formation between the leaves of clay minerals of a highly varied nature and requiring further investigations. The walls of the largely primary cavities are lined with clay minerals, mostly white or yellowish white but blue along the lower section of Zám Creek (Prédikáló Peak, Jánosvára). The hypo-metamagmatic clay mineral is largely nontronitic. In the fresh parts of the microandesite, e. g. along the upper sections of Fitó Creek and the Ülés valley as well as on the northern rim of the trachytic area on Hidegkút Peak, in the bronzitic pyroxene andesite of the middle series, one observes the intense oxidation of the dark minerals (bronzite-hypersthene), whereas the southern and southeastern parts (Nagy Creek) are characterized by celadonitization and carbonatization (Plate IV, Fig. 4, Plate V, Figs. 1—2). This process, particularly the carbonatization restricted to the marginal parts, also acted upon the felspars, mostly of labradoritic-bytownitic composition. In the intensely altered rock, in the andesitogenic potash trachyte the original dark constituents were completely decomposed.

The mineralogical composition of the metavolcanics of the Western Mátra Mountains as well as the areal diversity of that composition reveals without any place for doubt that in the region between the Tóthegyes and the Muzsla an endometavolcanic process of considerable duration and variable nature took place. The migration of the solutions giving rise to the process was governed by the dense network of NE—SW- and E—W-striking faults traversing the area. It was along these same faults that the horst-like uplift of Mount Hidegkút took place.

On the basis of the mineral constitution and the structure of the rock, two great phases are to be distinguished: *a)* the higher-temperature potash metasomatism, the formation of potash felspar, glauconitization and the development of quartz; and *b)* the lower-temperature hydrothermal silicification and the precipitation of chalcedony. As the latter process is evident even on

the youngest lava banks of the area, it is probable that the endometavolcanic processes connected with the origin of the vacuolar andesite went on with brief interruptions even after the end of the andesitic volcanism. The main phase of these processes is to be set at the time of the tectonic movements connected with the effusion of the upper andesite group.

The connection between potash metasomatism and propylitization was pointed out by several authors. As regards the origin of adularia frequent in the lodes of the Transylvanian mountains, MAURITZ stated as early as 1920 that "adularia is restricted to rather intensely altered 'propylitized' rock and there is reason to presume that its substances derive from the leaching of the host rock." The petrographic-geochemical principles underlying the process were clarified by SZÁDECZKY-KARDOSS (1958) and KORZHINSKY (1959). Their findings were confirmed also by SZÉKY-FUX's studies in the Tokaj Mountains. In the Mátra Mountains propylitization and potash metasomatism more or less resembling the processes observed in the Tokaj Mountains area are restricted to the Gyöngyösoroszi ore region southeast of the glauconitic potash trachytes.

The extremely high potash content of the potash trachyte of Hidegkút Peak can hardly be ascribed to the "leaching" of the andesite complex. The substantial alteration of the "middle plagioclase rhyolite tuff" constituting the lower level of the volcanic sequence suggests that K and Na have come, together with the ascending water, from the underlying clayey-sandy Helvetian series and from the Burdigalian "lower rhyolite tuff". According to DEGENS, HUNT, REUTER and REED (1964) increasing pressure results in the formation on the surface of clayey and sandy deposits of an ionic layer acting like a filter and keeping back the inorganic salts. As a result, then, of the overburden pressure generated by the volcanic sequence a potash-rich solution could have formed at a certain depth, a solution that by lateral migration could enter the volcanic pipe and through the latter also the superincumbent volcanic series. The further processes of the migration of potassium and of its infiltration into the lattices were already discussed by SZÁDECZKY-KARDOSS (1955, 1958, 1960).

The O_{Fe} index of the endomagmatic potash trachyte and of the analogous adularized rocks is exceedingly high as compared to that of hemiorthomagmatic trachyte, alkali trachyte and to that of the original and the surrounding acidic and basic orthomagmatic rocks (Fig. 4). It increases up to a certain limit with the increasing extent of potash felspar formation (Fig. 5). On this basis even the more exact delimitation of the meta- and orthomagmatic alkali rocks seems to be possible. In this respect the areal variation of the O_{Fe} indices of the Hungarian andesite varieties is rather remarkable, indicating that the somewhat higher alkali content of the andesites in the Börzsöny and Dunazug Mountains may be due to similar causes. As a result of potash metasomatism, potash becomes predominant among the alkalies, a fact that under

hydrothermal temperatures may result in a very basic medium. This may be the reason behind the strong oxidation of the iron and also behind the high O_{Fe} values (10 to 30) required by the formation of glauconite and celadonite. No further enrichment of potash is observed in the rock above that value. Consequently, further oxidation as revealed by the limonitization and goethitization of the glauconite is presumably a superficial exometamagmatic process.

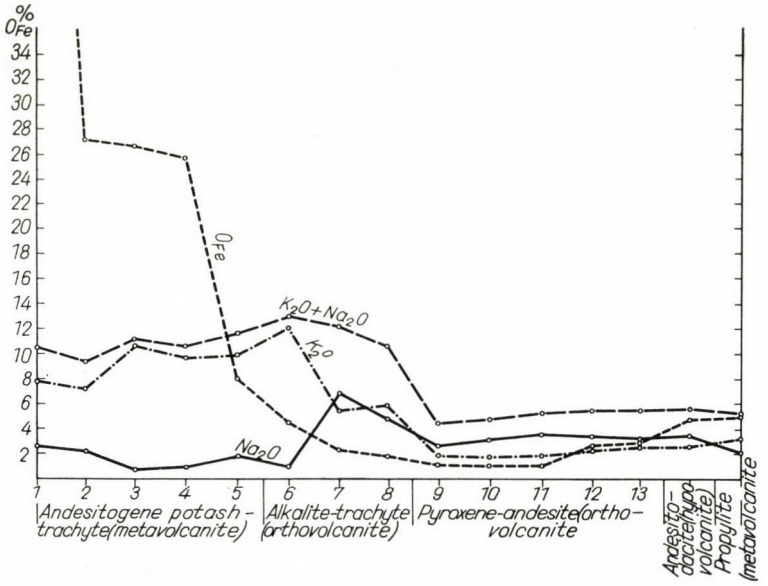


Fig. 4. Alkali content vs. degree of oxidation in trachytes and andesites. (xx): number of analyses

1. Metasomatized middle rhyolite tuff, Mátra Mountains, Aranybányafolyás. — *2.* Andesitogenic potash trachyte, Mátra Mountains (3). — *3.* Andesitogenic potash trachyte, Tokaj Mountains (11). — *4.* Andesitogenic trachyte from around Kremnica (14). — *5.* "Adularized quartziferous andesite" (andesitogenic potash trachyte), Baia Mare (7). — *6.* Trachyte, Dealul Tarda (7). — *7.* Alkali trachyte (4). — 8. Keratophyre (3). — *9.* Pyroxene andesite, Tokaj Mountains (11). — *10.* Pyroxene andesite, Mátra Mountains. — *11.* Pyroxene andesite, Cserhát Mountains. — *12.* Andesite, Börzsöny Mountains. — *13.* Andesite, Dunazug Mountains. — *14.* Andesito-dacite, Mátra Mountains (2). — *15.* "Propylitized andesite", Tokaj Mountains (2)

(The degree of oxidation of the chloritic rocks, likewise of a green colour, being considerably less [see Fig. 4], the O_{Fe} index also permits conclusions to be drawn concerning the possibility of glauconite and celadonite formation.)

The formation of sanidine and adularia in the course of potash metasomatism is consequently indicative, as pointed out by Széky-Fux (1964), of an intensely oxidizing medium, which is proved, besides the presence of the above minerals, also by the appearence of the characteristic "oxypyroxene".

The second phase of considerably lower temperature is revealed in the first place by the formation of abundant quartz and chalcedony, but in the trachyte it exerted locally an intensely decomposing influence. As a result of the acid solutions of the second phase, part of the potash felspar turned into clay minerals or eventually into sericite. A similar kaolinitization and sericitization was observed in the environs of Baia Mare (PÁLFY 1915, GIUȘCĂ

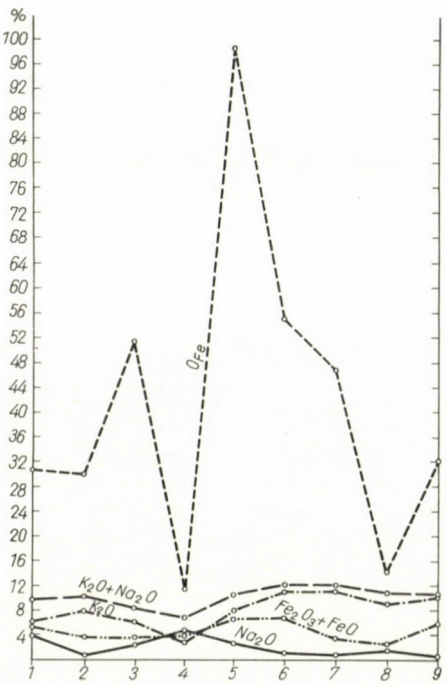


Fig. 5. O_{Fe} index vs. alkali content in andesitogene trachytes

1. Andesitogene potash silicotrachyte. Western Mátra Mountains, Mount Hidegkút. — *2.* Potash trachyte. Central Mátra Mountains, Feketető, east of Galyatető Peak. — *3.* "Decomposed andesite". Western Mátra Mountains, South of the Világos. — *4.* Silicic andesite. Western Mátra Mountains, 750 metres ESE of Világos Peak. — *5.* "Hydroandesite", Central Mátra Mountains, Aranybányafolyás. — *6.* Alkali trachyte. Tokaj Mountains, Kánya Hill. — *7.* Andesitogenic potash trachyte. Tokaj Mountains, Nagyszáva Peak. — *8.* Andesitogenic trachyte, Tokaj Mountains, Torpa Valley. — *9.* Adularized "quartziferous andesite", Baia Mare, Murgău Ridge

1961) and also in the Tokaj Mountains (SZÉKY-FUX—HERMANN 1951). It is by this process that we may interpret the fact that in highly altered areas the alkali content is much lower, even if the silicification is subordinate. This is confirmed also by a core of the Gyöngyösoroszi-II boring, in which the protracted hydrothermal influence decomposed most of the feldspar into sericite (Plate V, Figs. 3—4) or clay minerals. It was partly the silica liberated in the process that brought about the silicification of the upper levels.

The well-known relationship between potash metasomatism, propylitization and gold mineralization (PÁLFY, SZÁDECZKY-KARDOSS, SCHERF, SZÉKY-FUX, BÖHMER, etc.) cannot be demonstrated on Mount Hidegkút in the Mátra Mountains in the present state of disclosure. However, the funnel-like shape of the trachyte body, observed in the case of the potash trachyte of the Tokaj Mountains (SZÉKY-FUX 1964), can on the strength of tectonic and petrographic evidence be presumed also in the case of the Mátra Mountains.

As a summary we may state that in the formation of the diversified and widespread endometamagmatites the moisture-rich sedimentary series underlying and enclosing the volcanic series played a decisive role, in agreement with the conclusions arrived at by SZÁDECZKY-KARDOSS (1958—1960). Water, liberating and carrying the potassium, could mostly have been injected by overburden pressure into the tectonically loosened up zones, and through these latter, into the volcanic series. In other words, the water in question is of a transvaporizational origin. This fact is confirmed among others also by the peculiar alteration of the andesite tuff and schlier complex of the Gyöngyösoroszi-II boring (KUBOVICS 1964).

REFERENCES

BATTEY, M. H.: Geol. Mag. **92,** 104, 1955. — BÖHMER, M.: Geologické Práce **60,** 319. 1961. — BURST, J. F.: Am. Min. **43,** 481, 1958. — BYSTRÖM, A. M.: Acta Cryst. **7,** 772, 1954. — CHAISSON, U.: Journ. of Geol. **58,** 537, 1950. — DEGENS, E. T. et al.: Sedimentology, **9,** 199, 1964. — FIALA, F.—PÁCAL, ZD.: Niekolik geochemickych poznámek o kiselych diferenciátech neovulkanitu v Kremnickych horách. 1955. — GIUŞCĂ, D.: Acta Geol. Ac. Sci. Hung. **7,** 172, 1961. — GOLDSCHMIDT, J. R.—LAVES, F.: Geoch. et Cosmoch. Acta **58,** 1, 1954. — HENDRICKS, S. B.—ROSS, C. S.: Amer. Miner. **26,** 683, 1941. — HEJTMAN, B.: Nak. Česk. Ak. Ved. Praha. Systematická petrográfie vyvřelych hornin. 1957. — HSU, K. J.: Amer. Journ. Sci. **252,** 441, 1954. — KISS, J.: Ann. Univ. Sci. Budapestinensis, Sec. Geol. **3,** 55, 1960. — KÖHLER, A.: Neues Jahrbuch Sec. A. **5—8,** 49, 1948. — KORZHINSKY, D. SS.: Ocherk metasomaticheskich protsessov. Izd. Ak. Nauk SSSR, Moscow 1953. — KUBOVICS, I.: Földtani Közlöny **92,** 208, 1962. — KUBOVICS, I.: Jelentés a gyöngyösoroszi 2. sz. fúrás kőzettani—geokémiai vizsgálatáról. (Report on the petrographic and geochemical study of the boring Gyöngyösoroszi-II.) Manuscript. — KUBOVICS, I.: Acta Geol. Ac. Sci. Hung. **8,** 19, 1964. — LAVES, F.: Zeitschr. Krist. **113,** 265, 1960. — LIFFA, A.: Magyar Áll. Földt. Int. Évk. **41,** 1, 1953. — MACKENZIE, W. S.—SMITH, J. V.: Amer. Miner. **41,** 405, 1956. — MAURITZ, B.: Math. és Természett. Ért. **37,** 1920. — MOGAROVSKY, V. V.: D. AN SSSR. **151,** 1178, 1963. — NEMECZ, E.— VARJU, GY.: Földtani Közlöny **93,** 77, 1963. — PÁLFY, M.: Jahrb. d. kgl. ung. geol. Reichsanst. 442, 1915. — RADOSLOVICH, E. W.: Amer. Miner. **48,** 348, 1963. — RAVASZ-BARANYAI, L.—NAGY-MELLES, M.: Magyar Állami Földtani Intézet Évi Jel. az 1961. évről, **1,** 121, 1964. — SCHERF, E.— SZÉKY-FUX, V.: MTA Geokémiai Konf. Munk. Budapest, 1959. — SPENCER, E.: Min. Mag. **24,** 453, 1937. — SCHÜLLER, A.—WOHLMANN, E.: N. Jb. Min. Abh. **82,** 11, 1951. — SZÁDECZKY-KARDOSS, E.: Geokémia. Akadémiai Kiadó, Budapest 1955. — SZÁDECZKY-KARDOSS, E.: Földtani Közlöny **88,** 171, 1958. — SZÁDECZKY-KARDOSS, E.: MTA Geokémiai Konf. Munk. Budapest 1959. — SZÁDECZKY-KARDOSS, E.: Ibid., 1955. — SZÁDECZKY-KARDOSS, E.: Freiberger Forschungsh. C, **58,** 66, 1959. — SZÁDECZKY-KARDOSS, E.: A MTA Geokémiai Konf. Munk. Budapest 1959. — SZÁDECZKY-KARDOSS, E.: MTA Műsz. Tud. Oszt. Közl. **27,** 35, 1960. — SZÉKY-FUX, V.: Földtani Közlöny **94,** 409, 1964. — SZÉKY-FUX, V.—HERRMANN, M.: Földtani Közlöny **81,** 250, 1951. — TUTTLE, O. F.: Am Journ. Sci. Bowen **553,** 1952. — VARGA, GY.: Részjelentés a Nagygalya környéki földtani térképezésről. (Preliminary report on the geological mapping around Nagygalya Peak.) Manuscript. — VARGA-MÁTHÉ, K.: Földtani Közlöny **91,** 391, 1961. — VIDACS, A.: Magyar Állami Földtani Intézet Évi Jel. 1959-ről, 63, 1962. — YODER, H. S.—EUGSTER, H. P.: Geochim, et cosmochim. Acta **8,** 225, 1959.

РОЛЬ КАЛИЙНОГО МЕТАСОМАТОЗА В ОБРАЗОВАНИИ ВУЛКАНИЧЕСКИХ ПОРОД ЗАПАДНОЙ ЧАСТИ ГОР МАТРА

И. КУБОВИЧ

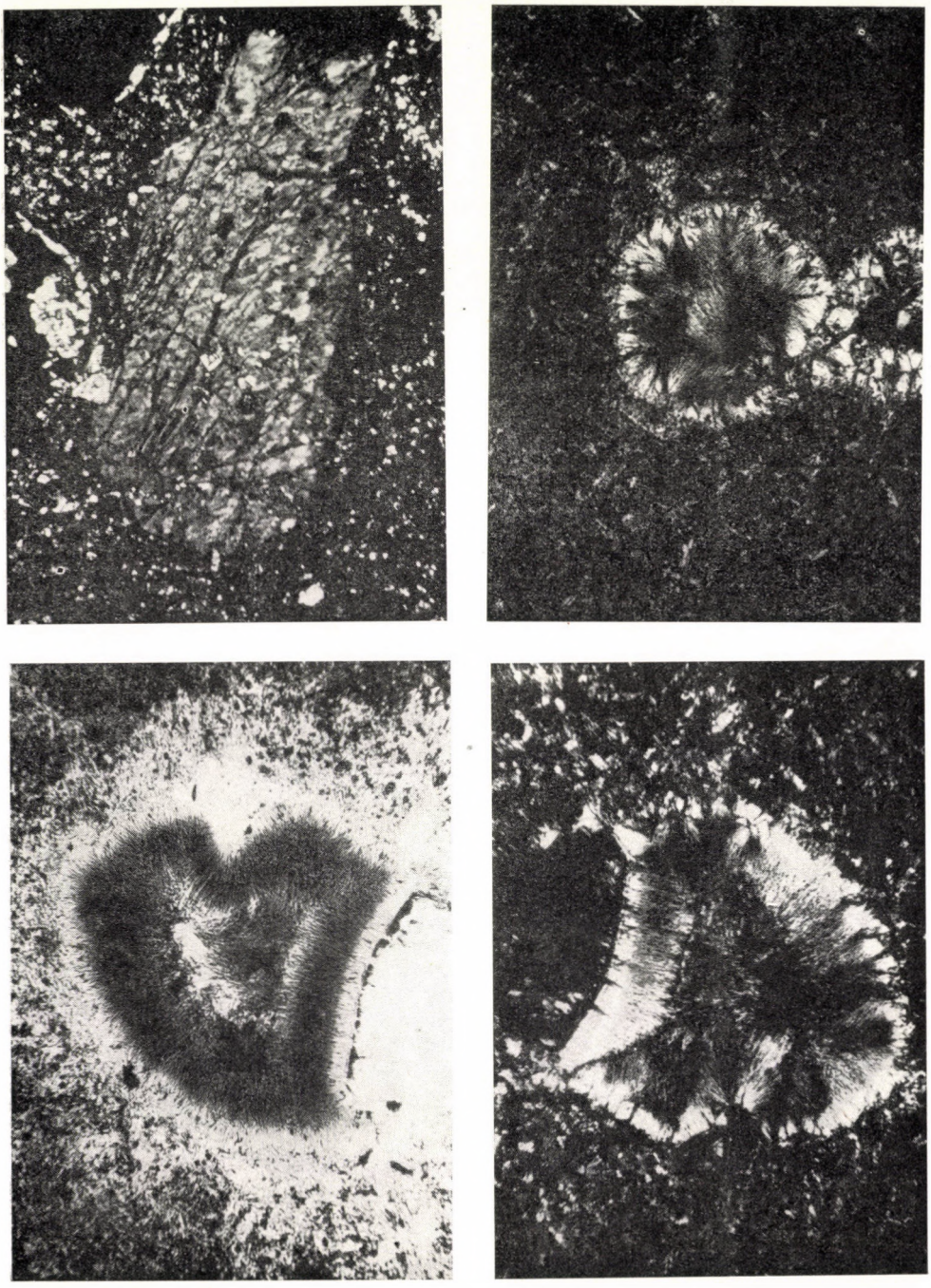
Р е з ю м е

Судя по минерало-петрографическому характеру вулканитов, в западной части Гор Матра имел место продолжительный и разнообразный эндометавулканизм, в результате которого образовалась значительная масса андезитогенных калиевых трахитов. По минералогическому составу пород можно выделить две большие фазы: а) калийный метасоматоз и б) гидротермальное окремнение. Приуроченный к более высокой температуре калийный метасоматоз проявился главным образом в формировании трех щелочных силикатов: санидин-адуляр, глауконит-селадонит и цеолит. Приуроченная к более низкой температуре вторая фаза привела в основном к образованию разновидностей SiO_2: кварца, а также разновидностей хальцедона, выполняющих полости и пустоты в породе.

Величина O_{Fe} эндометамагматических андезитогенных калиевых трахитов и аналогичных адуляризированных пород по сравнению с гемиортомагматическими и ортомагматическими горными породами, оказывается более значительным. Частично из этого вытекает связь между санидинизацией-адуляризацией, с одной стороны и глауконитизацией, требующей аналогично высоких значений O_{Fe}, с другой.

В образовании широко распространенных эндометавулканитов следует приписать решительную роль осадочному основанию с большой влажностью, что совпадает с результатами исследований Э. Садецки-Кардошша (1958—1960). H_2O, освободившая, несущая калий, могла попасть в тектонически разрыхленные зоны в первую очередь под влиянием пластовой нагрузки, и через тектонические зоны она была привнесена в вулканическую толщу; следовательно, ее можно рассматривать как образование трансвапоризационного происхождения.

Plate I



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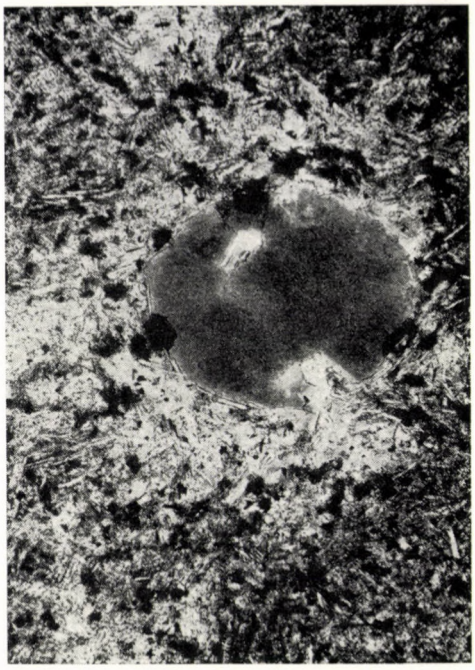


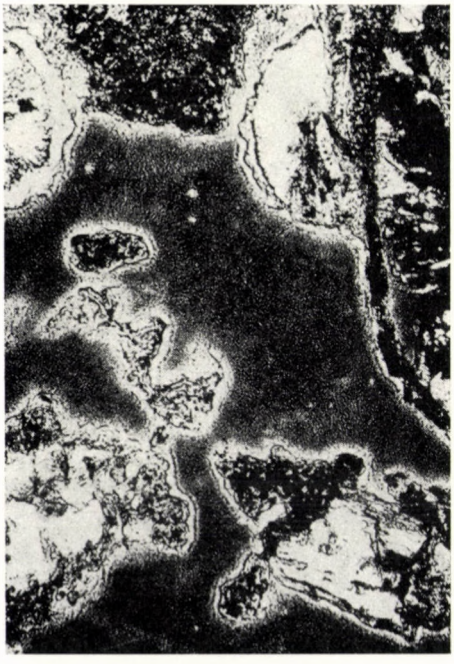
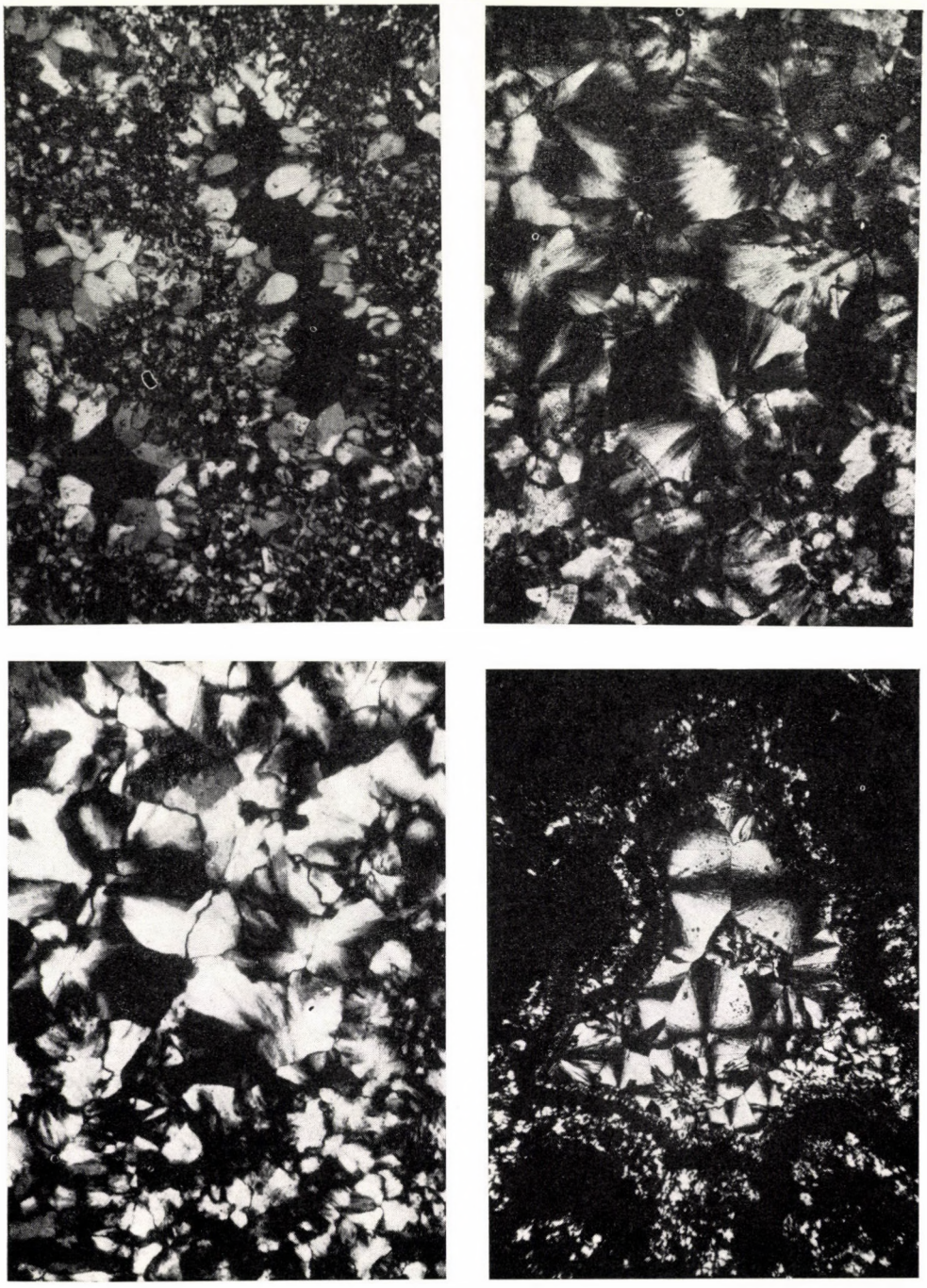


Plate III



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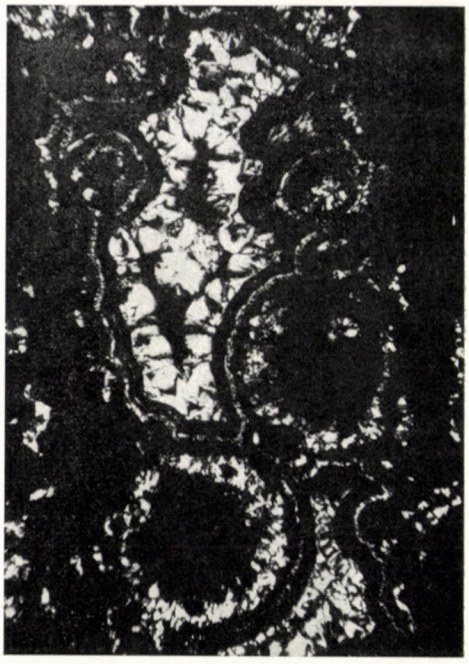

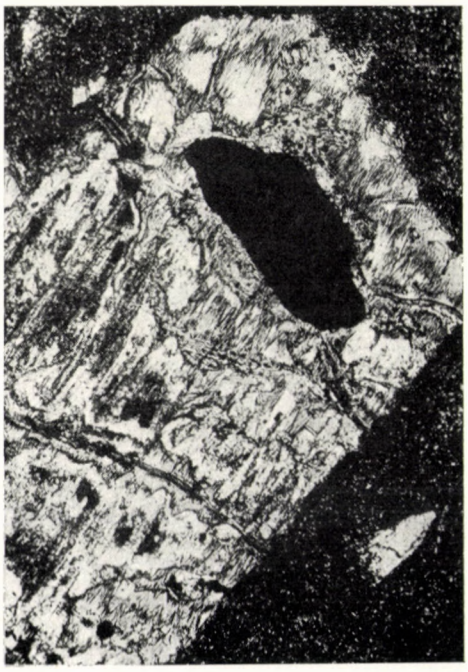

Plate V

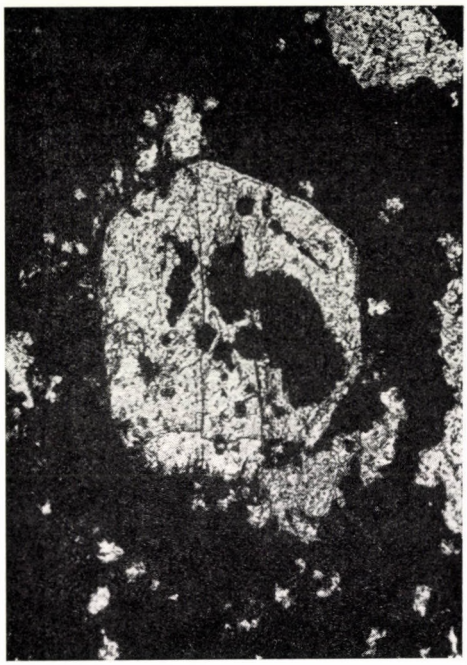

Plate I

1. Sanidine after plagioclase in andesitogenic potash trachyte. Western Mátra Mountains, Mount Hidegkút. Crossed Nicols. 60×. — 2. Glauconite with a clay mineral lining from vacuolar andesite. Western Mátra Mountains. Hegyeshegy Peak-Ülés Valley (middle andesite group). Crossed Nicols. 60×. — 3. Glauconite with a clay mineral lining from vacuolar andesite. Western Mátra Mountains, Hegyeshegy Peak—Ülés Valley (middle andesite group). One Nicol. 120×. — 4. Glauconite with a clay mineral lining from vacuolar andesite. Western Mátra Mountains, Hegyeshegy Peak—Ülés Valley (middle andesite group). Crossed Nicols, 120×

Plate II

1. Glauconite from microandesite. Western Mátra Mountains, Fitó Creek (middle andesite group). One Nicol. 60×. — 2. Glauconite from microandesite. Western Mátra Mountains, Fitó Creek (middle andesite group). One Nicol. 60×. — 3. Glauconite from pyroxene andesite, Western Mátra Mountains, Nagy Creek (middle andesite group). One Nicol. 120×. — 4. Glauconite from pyroxene andesite. Western Mátra Mountains (middle andesite group). One Nicol. 120×

Plate III

1. Cavity-filling quartz from potash trachyte, Western Mátra Mountains, Mount Hidegkút — Korlát. Crossed Nicols. 120×. — 2. Chalcedony from quartzite, Western Mátra Mountains, Nagyparlag, Crossed Nicols, 120×. — 3. Chalcedony from quartzite, Western Mátra Mountains, Nagyparlag. Crossed Nicols, 120×. — 4. Chalcedony and opal, Western Mátra Mountains, Muzsla Peak. Crossed Nicols. 120×

Plate IV

1. Chalcedony from potash trachyte, Western Mátra Mountains. Mount Hidegkút — Korlát. Crossed Nicols, 120×. — 2. Chalcedony, cristobalite and opal. Western Mátra Mountains, Muzsla Peak. Crossed Nicols, 60×. — 3. Chalcedony, cristobalite and opal. Western Mátra Mountains, Muzsla Peak, one Nicol, 60×. — 4. Celadonitized orthorhombic pyroxene from pyroxene andesite. Western Mátra Mountains, Nagy Creek (middle andesite group). One Nicol, 120×

Plate V

1. Calcite after pyroxene from andesite. Western Mátra Mountains, Nagy Creek (Middle andesite group). Crossed Nicols. 120×. — 2. Calcite after pyroxene from andesite. Western Mátra Mountains, Nagy Creek (middle andesite group). Crossed Nicols. 60×

FAZIESVERHÄLTNISSE IM UNGARISCHEN MIOZÄNEN ANDESITVULKANISMUS UND IHR BEITRAG ZUR VULKANOTEKTONISCHEN REKONSTRUKTION

Von

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Der vulkanologischen, tektonischen Rekonstruktion der karpatischen (und anderer) Andesitgebirge haften viele stereotype grobe Falschdeutungen an, die auf die irrtümliche Beurteilung der Bildungsverhältnisse der Andesitprodukte zurückzuführen sind. Neue Untersuchungen, die sich auf das Szádeczkysche Transvaporisations-Prinzip stützten, stellten klar, daß der Stratovulkantyp, bestehend aus Wechsellagerungen von Oberflächenlavaströmen und Aschenregentuffen (Agglomeraten) durchaus nicht allgemein, sondern exzeptionell ist. Eine weit größere Verbreitung haben die subvulkanischen Bildungen (intrusive Stöcke, Lagergänge mit pseudoagglomeratisch ausgebildeten Partien) und Submarine »peperitische« Erstarrungsprodukte. Ungarische Andesitgebirge liefern lehrreiche Schulbeispiele für beide vulkanische Fazies.

Irrtümliche Deutungen von Aufbau und Struktur dieser (und anderer ähnlicher) Gebirge können nur dann beseitigt werden, wenn Paläogeographie, Eruptionsfolge, Gesteinsbildung usw. statt »stratovulkanischer« Übertreibungen allgemein im Sinne der modernen petrologischen Auffassungen beurteilt werden.

Der vulkanologischen Faziesuntersuchung wird in der geologischen Bearbeitung vulkanischer Gebiete seit einem Jahrzehnt überall zunehmende Beachtung gewidmet. Dieses Interesse fußt auf der klaren Erkenntnis, daß eine vollständige Erklärung des geologischen Aufbaues vulkanischer Gebiete auf rein petrographischen oder stratigraphischen Grundlagen nicht möglich ist. In den klassisch schönen ungarischen miozänen vulkanischen Gebirgen, die schon bei der Begründung der vulkanischen Petrographie (BEUDANT 1822, RICHTHOFEN 1861) weithin bekannt geworden sind, ergab sich eine besonders scharfe Lücke. Bevor wir jedoch auf die Anwendung der musterhaft ausgearbeiteten komplexen Faziesmethode von TÖRÖK (1956) im einzelnen eingehen, erscheint es zweckmäßig, einen allgemeinen Überblick über Charakter, Ausmaß und Verbreitung der miozänen vulkanischen Vorgänge zu geben.

In der Paläovulkanologie galt die Übernahme der Erfahrungen der rezenten Vulkanologie von jeher als leitendes Prinzip. Eine enge und unmittelbare Anwendung und Anpassung scheiterte indes aus folgenden Gründen: 1. Die Spezialisten, die in der Untersuchung aktiver Vulkangebiete reiche Erfahrungen erworben hatten, wandten sich mit voller Aufmerksamkeit den Oberflächenvorgängen zu und entzogen sich der »tiefer« greifenden Betrachtung, die das »Reservat« der Paläovulkanologen (Forscher des tieferen vulkanischen Unterbaues — ohne persönliche Erlebnisse an tätigen Vulkanen) zu bilden schien. 2. Der rezente Vulkanismus bietet eine einseitige Beispielsammlung, die

den Ereignissen der Paläovulkanologie weder im Stoffbestand (Zusammensetzung) noch im Stil gleichkommt.

Eine scharfe zeitliche Trennung und Gegenüberstellung der paläo- und neovulkanischen Vorgänge (Leugnung des Aktualitätsprinzips in der Vulkanologie), wie sie von KLÜPFEL (1955, 1963) vertreten wird, scheint eine stark, wenn auch nicht ganz unbegründete Übertreibung zu sein. Die Unmenge von Fehldeutungen hat ihn zu dem Urteil gezwungen, die Paläovulkanologie hätte zur Erklärung ihrer Befunde die von der Vulkanologie beobachteten Prozesse in einem Maßstab vergrößert und verzerrt, wie er an der Oberfläche gar nicht zur Geltung kommen konnte.

Der erste Schritt jeder vulkanologischen Auswertung ist die grundlegende Entscheidung darüber, ob es sich um das Produkt eines extrusiv vulkanischen Vorganges handelt, das bei (oder nach) Erreichen der Tagesoberfläche erstarrt und zum Stillstand gekommen ist, oder um einen intrusiven (sub- oder tiefenvulkanischen) Gesteinskörper, dessen letzte Konsolidierung sich unter einer mehr oder weniger mächtigen Überlagerung abgespielt hat. Natürlich gibt es eine Vielzahl magmatischer Bildungen — vielleicht gewinnen sie für die ganze Erdoberfläche die Oberhand —, bei denen diese Unterscheidung auf keine besonderen Schwierigkeiten stößt. Wollten wir aber die miozänen Andesitgebirge Ungarns (Börzsöny, Cserhát, Mátra, Tokaj) und die ihrem Umfang nach weitaus größere vulkanische Decke des nordöstlichen vorpannonischen Beckenuntergrundes ausschließlich als Hinterlassenschaft des »Feuerspeiens« auf bzw. über der ehemaligen Erdoberfläche betrachten, würden wir einen groben Fehler begehen.

Als allgemeine und typische Erscheinungen der »echten« vulkanischen Tätigkeit gelten die Lavaströme und die Aschenregen, deren Gewaltsamkeit und Variabilität durch die tätigen Vulkane überwiegend basaltischer Zusammensetzung vielfach bewiesen wird. Den wiederholten Wechsel beider Erscheinungen erzeugt ein Stratovulkan, die so entstehenden Formationen können also als die meistverbreitete Bauform aller vulkanischen Gelände angesehen werden. Den »stratovulkanisch« aufgebauten Gebirgen und Landesteilen wurde aber nach den geologischen Übersichtskarten und Profilen ein Baustil zugeschrieben, der in der Mächtigkeit (< 500 m) der »Lavaströme« und in der Gleichmäßigkeit der Schichten die beim Entstehen beobachteten echten Stratovulkane ganz irreal übertrifft.

Die vorliegende Arbeit strebt keineswegs an, den Wechsel *geringmächtiger* (< 50 m) *echt andesitischer* ($< 55\%$ SiO_2) Lavaströme mit unregelmäßigen Andesittuff- und Agglomerat-Zwischenschaltungen vom ungarischen Miozänvulkanismus fernzuhalten. Die schönsten Beispiele liefert der Süd-Cserhát, sowohl im Börzsöny als auch in der Mátra und in Tokaj sind sie jedoch recht untergeordnet. Sie bilden ja nur lokale (< 5 km) Systeme die miteinander oft chaotisch verzahnt sind.

Selbst die reinst stratovulkanischen Gebirgsteile sind durchaus nicht frei von andesitischen Bildungen abweichender, »atypischer« Abstammung (keine Lavaströme und kein Auswurfsmaterial). Den sehr verschieden geformten unterschiedlich großen subvulkanischen Körpern mit ihrem unterschiedlichen Intrusionsniveau (Lakkolite, Dyke, Lagergänge, Stöcke) kommt in den meisten heute aufgeschlossenen sauerandesitischen bis dazitischen Gebirgsteilen eine größere Bedeutung zu als den echt-vulkanischen Oberflächenbildungen (Szádeczky-Kardoss 1958). Eine scharfe Trennung von ober und unter Tage entstandenen Andesitgebilden ist keineswegs leicht.

Um die Stichhaltigkeit der chronologischen Rekonstruktion zu schonen, müssen wir den Begriff Extrusion (Vulkanerscheinung im engeren Sinne) streng der Massenförderung auf die Oberfläche bzw. über dieser vorbehaltenen und alle »blinden« Vorgänge der intrusiven (subvulkanischen) Tätigkeit zuordnen (Pantó 1964). In diesem Sinne sollte die schlackige (glasige, blasige) »Haut« als sicheres Kennzeichen eines ehemaligen Lavastromes angesehen werden. Die Diagnostik ist natürlich dadurch erschwert, daß die obere »Haut« einer kürzeren Erosionsperiode leicht zum Opfer fällt und die untere selten aufgeschlossen ist.

Auch die abgedämpfte Konsolidierung einer Andesit- bzw. Dazitmasse läßt sich in den meisten Fällen nicht eindeutig beweisen. Das Auftreten der klassischen Kontakterscheinungen unterliegt einer Reihe von Bedingungen, die im subvulkanischen Bereich meist nicht erfüllt sind. Ob es sich um eine Unterströmung der magmatischen Schmelzen oder um eine nachfolgende Bedeckung (Überlagerung) der schon konsolidierten Andesit- (Dazit-) Gebilde handelt, kann nur durch eingehende strukturell-texturell-mineralogisch-geochemische Prüfung gut aufgeschlossener Kontakte einwandfrei entschieden werden. Eine solche Entscheidung ist (mangels guter Aufschlüsse und der erforderlichen Untersuchungskapazität) nur in Ausnahmefällen möglich. Die durchschnittliche Beurteilung mehrerer hundert Kontakte, auf denen das durch geologische Kartierung gewonnene Gesamtbild beruht, ist eine Verallgemeinerung.

Die durch Vergleich mit rezenten Vulkanbauten gestützte Auffassung, daß in den meisten paläovulkanologischen Rekonstruktionen sowohl die Rolle wie auch die Dimensionen der Lavaergüsse weit über die Grenzen der Wahrscheinlichkeit hinaus überschätzt (Fremd 1963, Klüpfel 1955, 1963), die (seichten) Tiefenvorgänge dagegen stark unterschätzt sind, soll auch für die karpatischen vulkanischen Gebirge als zutreffend angesehen werden. Bei der erforderlichen Umgestaltung der stereotypen »stratovulkanischen« Darstellung sollte man möglichst ohne jeden Schematismus vorgehen. Das tatsächlich chaotische Durcheinander effusiver und subvulkanischer Körper läßt sich jedoch nur an einigen besonders gut aufgeschlossenen Profilen erkennen. Am übrigen sind wir auf Inter- und Extrapolationen sowie Voraussetzungen ange-

wiesen, die nur eine mehr oder weniger einseitig vereinfachte Interpretation des Aufbaues ermöglichen. Wenn wir allerdings statt einer nach oben im Profil sich automatisch verjüngenden Reihe von Lavaergüssen — besonders bei Andesit-(Dazit-)Körpern größerer Mächtigkeit — auch mit subvulkanischen Injektionen rechnen, dürften wir der naturgetreuen Darstellung um einen Schritt näher kommen können.

Auf noch größere Schwierigkeiten stößt die richtige Erklärung, und ein noch breiterer Raum für Fehldeutungen ist gegeben auf dem Gebiet der nicht als massive Lava- (Magma-)Gesteine behandelten »Zwischenmittel« der stratovulkanischen Komplexe. Die mit den massigen und mehr oder minder homogenen Andesit- (Dazit-)Körpern wechsellagernde äußerst bunte Gesteinsgruppe, die meist als Andesitagglomerat erwähnt und teils wegen unzureichender Aufschlüsse, teils wegen Mangels an Spezialuntersuchungen meist nicht eingehender gekennzeichnet wird, birgt einen fast unerschöpflichen Reichtum genetischer Merkmale in sich, die leider öfters übersehen oder wegen einseitiger Verallgemeinerungen widersprechend gedeutet werden.

Den Agglomeratzwischenlagerungen wird, der allgemeinen Betrachtungsweise entsprechend, ohne eingehendere Überlegungen der *echt vulkanische* Bildungsweg (primäres Anhäufungsprodukt von Bombenstreuung und Aschenregen) zugeschrieben. Das kann in vielen Fällen zutreffen, ist aber bei weitem keine Gesetzmäßigkeit, die nach mancher, ohne Abwägung aller genetischen Merkmale gefaßten Meinung, eine über Tage sich abspielende Bildungsweise, einen atmosphärischen Transport des ganzen Materials, also eine zeitlich zwischen den Bildungsakten der liegenden und hangenden Lavaergüsse (falls es sich wirklich um solche handelt) gelegene *explosive* Wirkungsphase beweisen sollte.

Die besonders lebhaft diskutierte Frage der durch ungleichmäßige und verschiedenartige Zersetzung agglomeratähnlich gewordenen massigen Gesteine (Pseudoagglomerate, Szádeczky-Kardoss 1958) soll hier nicht als der wichtigste Teil dieses Problemkreises hingestellt werden. Allerdings unterliegt es keinem Zweifel, daß die Bedeutung und Wirksamkeit spät- und postmagmatischer Agenzien in der Umgestaltung vulkanischer Gesteine sowie deren täuschende Homologie mit echten (ausgeworfenen) Trümmergesteinen von Szádeczky-Kardoss richtig hervorgehoben wurde.

Die Pseudoagglomerate sind aber Endprodukte eines mehrphasigen und mehrfach zusammengesetzten (aus aszendenten und deszendentem Prozessen resultierenden) Umbildungvorganges. Die Umwandlungen (Zerfall und Neubildung mehrerer Generationen von Mineralphasen) gehen mit einem erheblichen Stoffaustausch einher, dem die ursprüngliche Textur und Struktur des Gesteins oft vollständig zum Opfer fällt. Da die genetischen Merkmale des Ausgangsgesteines, die die eigentliche Grundlage jeder vulkanologischen Rekonstruktion bilden, durch den Schleier der Zersetzung kaum auswertbar

sind, können nicht alle Pseudoagglomerate — also Gesteine mit scheinbaren Trümmern in scheinbarer Grundmasse — derselben Beurteilung unterzogen werden. Wollte man alle pseudoagglomeratisch ausgebildeten Gesteinskörper auf Grund des am unmittelbaren Saum der »*Pseudobomben*« feststellbaren Überganges von massigem Gestein in tuffähnliche »*Bindemittel*« als direkte unbewegte Erstarrungsprodukte großer zusammenhängender andesitischer Schmelzmassen deuten, beginge man einen ebenso groben Interpretationsfehler, wie wenn man alle diese Gesteinskörper von Aschenregen und Bombenstreuung herleiten würde.

Die tatsächliche Abstammung der Andesitgebirge führt über zahlreiche denkbare Entstehungsweisen, die die Bildung heterogener, im Endprodukt »agglomeratisch« aussehender vulkanischer Aggregate über eine breite Skala von Phänomenen ermöglichen, deren Grenzfälle die homogene Lavaerstarrung und die explosive Trümmerstreuung darstellen. Die durch diese Konvergenzerscheinung bedingten Schwierigkeiten der Enträtselung der vulkanischen Entwicklungsgeschichte können zwar in manchen Fällen selbst durch eine noch so tiefgreifende Untersuchung der Agglomerate kaum überwunden werden, doch kann eine großräumige Analyse des vulkanischen Baustils, die allen Zwischenfällen Rechnung trägt, zur Auflösung der Widersprüche nützlich beitragen.

Es kann vielleicht als eine Besonderheit der ungarischen Andesit- (Dazit-) Gebirge (Börzsöny, Mátra, Tokaj) angesehen werden, daß sie entlang und unterhalb der heutigen Abtragungsfläche durch das vollständige Fehlen oder durch die auffällige Seltenheit echter Auswurfsagglomerate gekennzeichnet sind. Agglomeratisch zersetzte oder verwitterte Bildungen gibt es auch hier, manchmal in starkem Übergewicht vor den homogenen Andesit- (Dazit-) Massen. Sie sind teils an submarine, teils an subvulkanische Komplexe gebunden und können im Sinne der obigen allgemeinen Definition als Pseudoagglomerate angesehen werden. Sie sind generell auf zwei vulkanische Erscheinungsgruppen zurückzuführen, u. zw. auf das submarine und auf das subvulkanische Eindringen und auf die nachfolgende Konsolidierung andesitischer Schmelzen, die sich bei außerordentlicher Volatilanreicherung abspielt.

Die beiden Gruppen lassen sich kurz folgendermaßen kennzeichnen:

Als submariner Vulkanismus soll die am Meeresboden austretende oder die noch gar nicht konsolidierte, frische Sedimente durchdringende magmatische Massenförderung betrachtet werden. Diese Art der vulkanischen Tätigkeit scheint im ungarischen Tortonvulkanismus (Mátra, Tokaj) recht verbreitet gewesen zu sein. Ihre Erscheinungsformen und Produkte sind aber so mannigfaltig, daß sie bisher weder einheitlich beschrieben, noch in ihrem genetischen Zusammenhang erörtert wurden.

Die aus bald massigen, bald bröckeligen, ja selbst aus mit Sedimentmaterial zusammengequetschten, zunehmend entarteten Gesteinen bestehenden

submarinen Komplexe konnten erst in den letzten Jahren auf Grund günstiger (künstlicher und natürlicher) Aufschlüsse enträtselt werden. Gleichviel, ob man von *Pépérit, Hyaloclastit* oder »*pillowed lava pod*« spricht (MICHEL 1953, CUCUZZA-SILVESTRI 1963, SNYDER-FRASER 1963), immer handelt es sich um dieselbe Phänomene, freilich in recht verschiedener Reihenfolge, Intensität und Wechselwirkung.

Die bisher näher untersuchten Vorkommen Füzérkajata (ERHARDT 1964), Tállya (GYARMATI 1965), Tar (KUBOVICS 1963) bestätigen, daß der einleitende tortonische submarine Andesitvulkanismus sowohl in der Mátra wie im Tokajer Gebirge zur Bildung recht mächtiger Komplexe geführt hat, die bisher als Stratovulkane aufgefaßt wurden. Die eingehende Prüfung der Struktur und Textur sowie des Mineralbestandes liefert zuverlässige Beweise dafür, daß diese teils aus massigen Andesitkörpern, teils aus gröberen oder feineren Andesittrümmern — natürlich keineswegs schichtenweise — aufgebauten Komplexe Ergebnisse eines einheitlichen, lang andauernden, ruckweise aufschwingenden, submarinen Lavaaustrittes sind.

Die zuerst austretenden Lavazungen zerfallen, an Volatilen bis zur Autoexplosivität übersättigt, oft in unregelmäßige gröbere oder feinere Bruchstücke, die weniger »angedunsteten« reichlichen Nachschübe intrudieren, injizieren oder unterströmen die früheren Erstarrungsprodukte und bilden so mehr oder weniger zusammenhängende und einheitliche Andesitkörper. Da das Trümmermaterial sehr verschiedene Anhäufungen (direkte Ablagerung, Fortschaffung, Vermischung mit Sedimentmaterial durch erhitzungsbedingte heftige Meeresströmungen, Verschluckung durch späteren Lavaaufstieg) und Verfestigungsprozesse durchmacht, die chaotisch ineinandergreifen, kann die Linie der Gesteinstypenabstammung nur mit Sorgfalt verfolgt werden. Der tortonische submarine Andesitkomplex, der in der Bohrung Tállya-15 in beinahe 400 m Mächtigkeit aufgeschlossen wurde, übertrifft an Schönheit und Variabilität die Aufschlüsse des Grand Limagne (MICHEL 1953) und von Unalaska Island (SNYDER-FRASER 1963).

Wenn wir die petrographischen Merkmale der einzelnen Typen und Glieder dieses Komplexes nachprüfen, begegnen wir äußererst schwierigen terminologischen Problemen und verlieren den Überblick über das Ganze. Unter den Gesteinsgliedern gibt es reichlich Andesite (spät- oder postmagmatisch in verschiedenen Graden entartet) und reine Pyroklastika, ja sogar sedimentvermengte Tuffite. Besonders häufig sind aber die Übergangsglieder, die eben zersprungenen unvollkommen aufgelockerten Andesitschollen, die in ihrer Primärausbildung kaum als vulkanische Trümmergesteine angesehen werden können. Spät- und postvulkanische Agenzien waren in diesem submarinen Milieu besonders aktiv und wirkten durch inhomogene (wegsamkeitsbedingte) Zersetzung in Richtung der pyroklastischen Beschaffenheit. Manchmal ist es recht schwer, die primären klastischen Kennzeichen von den sekundär erwor-

benen zu unterscheiden. Da aber der Werdegang des ganzen Komplexes viel mehr effusiven und intrusiven Prozessen als explosiven zuzuschreiben ist, begehen wir in der vulkanologischen Rekonstruktion m. E. einen kleineren Fehler, wenn wir den Anteil des primär nicht locker gewesenen Materials überschätzen.

Nicht minder verwickelt sind die subvulkanischen Prozesse, die sich im Inneren des aus dem Wasserspiegel schon herausragenden vulkanischen Gebirges abspielen.

Ihre Bedeutung muß wegen ihrer Massenförderung sowohl an dicht (in Stöcken, Dykes, Sills) als auch an locker konsolidierendem andesitischem Material besonders für den Börzsöny, die Mátra und für das Tokajer Gebirge stark unterstrichen werden. Vom Standpunkt der vulkanologischen Rekonstruktion aus ist diesen mehr oder weniger berechtigt als Pyroklastika bezeichneten Bildungen besondere Aufmerksamkeit zu widmen. Die Anordnung der Agglomerate innerhalb des Komplexes spiegelt in vielen Fällen ihre mit dem Eindringungsprozeß verbundene Entstehungsweise wider.

Subvulkanische Pyroklastitbildung wurde schon öfters als ein Ausnahmefall erwähnt (»Daugbildung«, blinde Schlotausfüllungen und Trümmergänge), aber niemals als eine zwangsmäßige und verbreitete Begleiterscheinung der in geringen Tiefen verborgenen vulkanischen Tätigkeit. Die noch vor dem Erreichen der Erdoberfläche eintretende »Pyroklastisierung« ist eigentlich eine durch übermäßige Volatilaufnahme bedingte Entartung und Auflockerung der sonst zu zusammenhängenden Andesit- (Dazit-)Massen erstarrenden Schmelze. Sie ist am intesivsten dort, wo die Berührungsfläche der eindringenden Schmelze besonders groß und der Magmaaufstieg nach längerem »Reifen« (Hypomagmenbildung im Sinne von Szádeczky-Kardoss 1958, 1960) einen Sprung mitmacht.

Bei diesen »pyroklastisch« gewordenen Intrusionskörpern, deren Auflockerung, den Entstehungsbedingungen entsprechend, sich nur auf einen Mantel beschränkt oder auch den Kern erreicht, ist es schwer zu entscheiden, bis zu welchem Grad die Zergliederung und Veränderung zum Zeitpunkt der Platznahme fortgeschritten war und in welchem Maße sie sich später weiterentwikkelt hat. Allerdings ist auch der »unterirdische« mechanische Auflockerungsprozeß, von welchem bisher sehr wenig gesprochen wurde, nicht zu unterschätzen. Bei der weiteren, postmagmatischen Entwicklung erwiesen sich selbstverständlich die zersprungenen Partien gegen die chemische Zersetzung am meisten empfindlich und ihr am leichtesten zugänglich. In der unmittelbaren Wand der Zufuhrbahnen ist die Veränderung meist bis zum Hydroandesitstadium fortgeschritten und unter den frischer erhaltenen Andesitinseln bildet sich ein tuffartiges Bindemittel. Die Zunahme des Bindemittels auf Kosten der »Inseln« ist ein mehrere Phasen durchlaufender Vorgang, der auch massive Andesitkörper (und alle Zwischenglieder) bis zu den echten Agglomeraten den Pyroklastika schrittweise immer näher bringt.

Wenn wir es nun wagen wollen, die Konsequenzen aus den obigen petrogenetischen Betrachtungen hinsichtlich der Gesamtstruktur der Gebirge zu ziehen, so müssen wir von beiden Auffassungen über die vulkanischen Profile, daß nämlich 1. jeder Gipfel einen Eruptionskegel mit Schlot unterhalb der Kote darstellt, und daß 2. Stratovulkane aus regelmäßigen Schichtpaketen bestehen, die auf Entfernungen bis zu 50 km von mächtigen »Lavaströmen« durchsetzt sind — wenigstens hinsichtlich unserer Andesitgebirge — endgültig Abschied nehmen.

Wie schon erwähnt, verfügen wir noch immer nicht über Strukturangaben in ausreichender Fülle, um die Kluft zwischen einfachen, aber täuschenden Schemen einerseits und der äußerst verwickelten Realität andererseits zu überbrücken. Einseitigkeit der vertikalen Gliederung (unabhängige Kegel) kann auf größere vulkanische Einheiten ebensowenig passen wie die Übertreibung der Bedeutung der horizontalen Ausdehnung und Gleichmäßigkeit. Die auf neuer Basis durchzuführende Rekonstruktion soll Klarheit über eine individuelle strukturelle Prädisposition von Gebirge und Gebirgsteile bringen, die nicht nur den Baustil, sondern auch die petrogenetische Entwicklung bestimmt.

LITERATUR

1. BEUDANT, F. S.: Voyage minéralogique et géologique en Hongrie 1—3 + atlas. Paris, 1822. — 2. CUCUZZA-SILVESTRI, S.: Bull. Volc. **25,** 315—321, 1963. — 3. ERHARDT, GY.: Földtani Intézet Évi Jelentése az 1962. évről 391—426, 1964. — 4. FREMD, G. B.: Trudy Lab. Paleovulk. **1,** 5—11, 1963. — 5. GYARMATI, P.: Földtani Intézet Évi Jelentése az 1964. évről 1965 (in Vorbereitung). — 6. KLÜPFEL, W.: Forsch. u. Fortschr. **29,** 321—325, **12,** 357—361, 1955. — 7. KLÜPFEL, W.: Geol. Rundschau **52,** 514—539, 1963. — 8. KUBOVICS, I.: Földtani Közlöny **93,** 466—480, 1963. — 9. MICHEL, R.: Publ. Fac. Sci. Univ. Clermont Lab. Géol. Min. **1,** 1—140, 1953. — 10. PANTÓ, G.: Acta Geol. Acad. Sc. Hung. **8,** 83—96, 1964. — 11. RICHTHOFEN, F.: Jahrb. k. k. geol. RA. **2,** 153—278, 1861. — 12. SNYDER, G. L.—FRASER, G. D.: U. S. Geol. Survey Prof. Paper **454,** 1—23, 1963. — 13. SZABÓ, J.: Jahrb. k. k. geol. RA. **16,** 82—97, 1866. — 14. SZABÓ, J.: Selmec környékének geológiai leírása. Magyar Tud. Akad. III. Oszt. kiadványa 1891. — 15. SZÁDECZKY-KARDOSS, E.: Acta Geol. Acad. Sc. Hung. **6,** 197—233, 1958. — 16. SZÁDECZKY-KARDOSS, E.: Materialy 4. Sjezda Karpato-Balkanskoj Assoc. N° **2,** 40—59, 1960a. — 17. SZÁDECZKY-KARDOSS, E.: Congr. Geol. Internat. XXI. Session Report Sect. 13, 260—274, 1960b. — 18. TÖRÖK, Z.: Studii şi Cercetări de Geol.-Geogr. Acad. RPR. Filiale Cluj **7,** 71, 1956.

FACIOLOGICAL FEATURES OF THE HUNGARIAN ANDESITE VOLCANISM AND THEIR CONTRIBUTION TO THE VOLCANO-TECTONICAL RECONSTRUCTION

By

G. PANTÓ

Abstract

Numerous stereotype rough misinterpretations traceable back to an erroneous judgment of the conditions of development of andesite products adhere to the volcanological, tectonical reconstruction of the Carpathian (and other) andesite mountains. Recent investigations, based on SZÁDECZKY's transvaporization theory, proved that the stratovolcano type consist-

ing of alternating depositions of surface lava streams, and ash-fall tuffs (agglomerates) resp. is by far not a general case but rather an exception. Much more widespread are the subvolcanic formations (intrusive stocks, sills with parts of pseudo-agglomeratic development) and sub marine »pépéritic« products of solidification. Typical instructive instances for both volcanic facies are furnished by the andesite mountains of Hungary.

Misinterpretations of the constitution and structure of these (and similar other) mountains can be eliminated only if palaeogeography, eruptional sequence, petrogenesis, etc. are judged — not on the lines of »stratovolcanic« exaggerations — but in the general sense of up-to-date petrological notions.

ФАЦИАЛЬНЫЕ УСЛОВИЯ АНДЕЗИТОВОГО ВУЛКАНИЗМА В ВЕНГРИИ И ИХ ИСПОЛЬЗОВАНИЕ В ВУЛКАНОТЕКТОНИЧЕСКОЙ РЕКОНСТРУКЦИИ ВУЛКАНИЧЕСКИХ РАЙОНОВ

Г. ПАНТО

Р е з ю м е

С вулканотектонической реконструкцией Карпатских (и других) андезитовых массивов связаны многочисленные, как бы стереотипные примеры ошибочных толкований, обусловленных неправильным подходом к анализу условий образования продуктов андезитового вулканизма. Новейшими исследованиями, базировавшимися на предложенном Э. Садецки-Кардошшом принципе трансвапоризации, было установлено, что представленный переслаивающимися поверхностными лавовыми потоками и продуктами туфовых выбросов (агломераты) стратовулканический тип отнюдь не является обычным, а исключительным типом. Гораздо более широко распространены субвулканические образования (интрузивные штоки, пластовые жилы с псевдоагломератовыми частями) и подводно-морские «пепе ритовые» продукты затвердевания. Венгерские андезитовые массивы предоставляют классические примеры для обоих фациальных типов.

Ошибочные толкования в отношении строения и структуры этих (и других сходных) массивов смогут быть устранены только тогда, когда палеогеографические условия, последовательность извержений, петрогенез и т. п. будут оцениваться вообще в смысле современных петрологических концепций, без всяких преувеличений «стратовулканического» характера.

MIOZÄNE TUFFHORIZONTE UNGARNS

Von

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Die wichtigsten Erscheinungen der tertiären vulkanischen Geschichte Ungarns sind die weiträumigen Fluttuffbedeckungen (6—40 000 km²). Sie stellen besondere oberflächennah entwickelte Massenproduktionen des Pannonischen Massivs dar, deren Schwerpunkt im ignimbritischen (Schweißtuff-) Feld liegt. Wegen ihrer großen Ausdehnung und kurzen Bildungsdauer kommt ihnen eine besondere — alle anderen Pyroklastite des Karpatenbeckens weit übersteigende — stratigraphische Bedeutung zu.

Ihre lang eingebürgerte Benennung ist: »unterer« Rhyolithtuff (Burdigal), »mittlerer« Rhyolithtuff (Torton) und »oberer« Rhyolithttuff (Sarmat). Die mineralogisch-chemische Zusammensetzung der bunten, oft 1000 m Mächtigkeit überschreitenden Tuffkomplexe schwankt um das (plagioklas) rhyolithische-dazitische.

Die Untersuchung der tertiären Tuffhorizonte hat im Karpatenbecken alte Traditionen. Zu Beginn (1879) wurde die stratigraphische Niveaubeständigkeit der Tuffhorizonte in Siebenbürgen [Tuffe von Dés (Dej) und Gyéres (Ghiriș)] nachgewiesen. Erst später entwickelte sich die stratigraphische Gliederung der Beckenausfüllungen (in erster Linie der Braunkohlengebiete), und diese stützte sich auf Tuffschichten und Decken als Leithorizonte (GY. SZÁDECZKY, 1912, 1914).

Zu einer vulkanologischen Revision der Tuffhorizonte reicht die mineralogische und stratigraphische Beschreibung der pyroklastischen Einheiten nicht aus. Moderne petrologische Arbeiten wurden zuerst in den vulkanischen Gebirgen in Angriff genommen und die Klärung der grundsätzlichen genetischen Fragen zieht sich langsam in die Beckengebiete hinein. Was wir heute generell behaupten können, enthält noch viel Interpolationen. Verallgemeinerungen dürfte aber nach unserer Meinung in großen Zügen fest begründet sein.

Um einer Analyse der *das ganze Land umfassenden* vulkanischen Erscheinungen näher zu kommen, müssen wir die Faziesverhältnisse der Tuffdeckenbildungen — die sich in deren Gesteinsmaterial widerspiegeln — in ihrem Verhältnis zu jenen der eingehender studierten vulkanischen Gebirge betrachten. Im Tokajer Gebirge, wo die für unsere Analyse besonders wichtigen sauren Pyroklastika in besonderer Fülle und Mannigfaltigkeit vorhanden und wegen ihres Gehaltes an Nichterzen einzigartig gut aufgeschlossen und untersucht sind, scheint es in jeder Hinsicht begründet zu sein, folgende genetische (vulkanfazielle) Hauptkategorien zu unterscheiden:

1. *Flut-Tuffe* (flood tuff, ash-flow tuff), unterteilt nach dem Grad der Verfestigung bzw. Verschweißung des Materials.

2. *Aschenregen-Tuffe* (von vulkanischen Aschenwolken kalt abgesetzte Tuffe).

3. *Umgelagerte Tuffe* (durch Wiederaufarbeitung aus dem Material der ersten beiden Gruppen entstanden).

4. *Tuffite* (mit mehr als 30% Sedimentmaterial vermengte pyroklastische Gesteine, entstanden entweder durch die die Sedimentation begleitende Tuffstreuung oder durch Mischung bei der Umlagerung).

Natürlich sind die geologisch selbständigen und stratigraphisch einheitlich zu behandelnden Pyroklastitkörper (Decken) genetisch bei weitem nicht homogen. Die getreue Wiedergabe der echten Variabilität, d. h. die getrennte Darstellung aller materiell und genetisch homogenen Einheiten, kann auch bei Detailaufnahmen kaum erreicht werden (z. B. ZELENKAS Gliederung [1961] für den Tuffkomplex der Umgebung von Mád). Um eine Übersicht erhalten zu können, bedürfen wir natürlich einer starken Generalisierung und Abstraktion der Eigenart dieser Gesteine, weshalb die stratigraphischen Einheiten nur mit dem dominanten Typ gekennzeichnet werden können.

In den tertiären Tuffhorizonten Ungarns begegnen wir meist Magma- bzw. Lavaprodukten, die sauerer als echte Dazite sind und üblicherweise als Rhyolithe oder als Dazite resp. deren Tuffe angesehen werden. Die Terminologie hat hier ihre »historischen« Fehler, die bis auf RICHTHOFEN zurückreichen. Ein plagioklasfreier Rhyolith, also ein der ursprünglichen, gerade für das Gebiet von Tokaj aufgestellten Definition entsprechendes Gestein, liegt in Ungarn eigentlich überhaupt nicht vor. RICHTHOFENS (1861) falsche Feldspatbestimmung wurde durch den von GY. SZÁDECZKY (1890) eingeführten Namen »Plagioklasrhyolith« berichtigt. Diese Bezeichnung mit der zugehörigen klaren Definition erhielt eine weltweite, selbst auf Neuseeland anwendbare Gültigkeit, da diese Gesteinsart (mit Plagioklasvormacht über K-Feldspat) eigentlich der vorherrschende Typus in allen sauren jungvulkanischen Gesteinsprovinzen ist. Wie weit unter »Rhyolith« Plagioklasrhyolith verstanden wird, bleibt weitgehend der willkürlichen Beurteilung überlassen, aber es gibt Ansichten (englische Schule), nach denen die Bezeichnung »Rhyolith« den K-Feldspatgesteinen reserviert werden sollte und alle sauren Vulkanite mit Plagioklasüberschuß »Dazit« genannt werden sollten.

Beiläufig soll erwähnt werden, daß die K-Feldspat-Fenokristalle, deren Menge auch in den K-reichsten Gesteinen unter jener der Plagioklase bleibt, keine typische Sanidine (mit 2V unter 10°), sondern Übergangstypen zu Orthoklas (2V bis 40°) sind. Sie können also nur als Sanidine i.w. S. (z. B. MARFUNIN 1962) bezeichnet werden. Das hängt außer den Bildungsbedingungen (keine echte Lavaeffusionen und keine rasche Abkühlung), auch mit dem großen Na_2O-Gehalt in der K-Feldspat-Phase zusammen.

Als (Plagioklas) Rhyolithe werden im Tokajer Gebirge auf Grund petrochemisch-mineralogisch ausgewerteter mehr als 100 Analysen Gesteine mit 69—75% SiO_2-Gehalt angesprochen. Eine weitere chemische Gliederung dieser Kategorie — durch effusive Äquivalente der mineralogisch enger definierten granitischen Gesteinstypen — wäre sehr erwünscht. Ein höherer SiO_2-Gehalt wird immer der nachträglichen Silifizierung zugeschrieben. Unter den Gesteinen der Tuffhorizonte sind solche mit niedrigerer Azidität recht verbreitet, ja sogar überwiegend. Sie wurden teils den Daziten, teils den Rhyolithen zugeteilt, meist auf Grund der Ab- oder Anwesenheit des fenokristallinen Quarzes. Die Unhaltbarkeit dieser Gesteinsbenennung, die auf den durchschnittlich 20% des Gesamtvolumens nicht überschreitenden Fenokristallen basiert, wurde schon dargelegt (GYARMATI 1961). Die chemische Analyse, die sich auf die ganze Gesteinsmasse bezieht, soll hier als weit verläßlicher angesehen werden. Auf petrochemischer Grundlage wurden im Tokajer Gebirge Vulkanite mit 60—65% SiO_2-Gehalt als Dazite, jene mit 65—69% SiO_2 als Rhyodazite definiert.

Das Umtaufen der pyroklastischen Gesteine der Tuffhorizonte auf Grund solcher petrochemischer Prinzipien steht bisher noch aus. Der Grund dafür liegt in der unzureichenden Zahl der Analysen und in vielen Fällen auch darin, daß das Tuffgestein nicht das reine Eruptivmaterial repräsentierte. Der großen Übersicht halber kann festgestellt werden, daß das Häufigkeitsmaximum der tertiären Tuffe im Rhyodazitbereich liegt. Die Schwankungen zur Dazit- bzw. Rhyolithseite hin sind nicht eindeutig magmatisch begründet, und Niveaubeständigkeit haben sie nur innerhalb kleinerer Gebietseinheiten.

Von den Andesittuffschichten Ungarns stellte es sich frühzeitig heraus, daß sie an verschiedene nicht synchrone Ausbruchszentren (Spaltensysteme) geknüpft sind, die oft mit den vulkanischen Gebirgen zusammenfallen und denen regional (500—1000 km) keine Niveaubeständigkeit zuzuschreiben ist. Deshalb lassen wir jetzt diese Tuffe unbeachtet, obzwar ihr stratigraphischer Bereich viel umfassender (vom Eozän bis zum Pannon reichend) ist als jener der sauren Tuffe (Burdigal bis Obersarmat).

Die miozänen, weit ausgedehnten, horizontbildenden Tuffe in Ungarn lassen sich unter drei historischen Benennungen zusammenfassen: »*unterer*«, »*mittlerer*« und »*oberer*« *Rhyolithtuff*. Da diese Benennungen stark eingebürgert sind und mit manchen Einschränkungen wichtigen und weithin brauchbaren stratigraphischen Wert haben, wollen wir diese Namen benützen, auch wenn diese Tuffe nicht rein rhyolithischer Zusammensetzung sind und auch wenn ihre Niveaubeständigkeit vulkanologisch nicht als ganz allgemein gültig aufzufassen ist.

Es war eine unvermeidliche Notwendigkeit, die Tuffhorizonte Ungarns von ihren »Quellgebieten« getrennt und meist rein stratigraphisch zu behandeln, da sie, ihrem Bildungsmechanismus entsprechend, breit ausgedehnte Decken

bilden, ohne den genauen Zusammenhang der notwendigerweise vorhandenen Zufuhrkanäle oder -spalten mit besonderen »zentralen« Vulkangebilden zu verraten. Deshalb sind wir über die Ausbruchszentren noch immer in vielen Fällen schlecht unterrichtet. Außerdem ist es selbstverständlich, daß die peripheren Teile, die weiten Ausläufer der Tuffdecken, die in stratigraphisch wohl datierte Schichtenfolgen allein oder voneinander weit getrennt eingeschaltet sind, chronologisch viel genauer auswertbar waren als die zentralen Äquivalente, wo sie ohne sedimentäre Zwischenschaltungen aufeinandergehäuft vorkommen. Für die Nähe der Ausbruchszentren ist jedenfalls die riesige Mächtigkeitszunahme der Tuffhorizonte (über 1500 m) und das gleichzeitige Ausbleiben des nächsten sedimentären Liegenden bzw. Hangenden charakteristisch.

Die vulkanischen bzw. paläogeographischen Faziesverhältnisse der einzelnen Tuffhorizonte sind vertikal und horizontal recht veränderlich. Als Haupttyp ist im allgemeinen der Fluttuff zu bezeichnen. Der Mechanismus der Aschenströme hat die riesige Menge (von insgesamt mehr als 30 000 km^3) saueren pyroklastischen Materials zur Tagesoberfläche gefördert und dessen spezielle Verteilungs- bzw. Erstarrungsverhältnisse bestimmt. Die Intensität und Verbreitung der Verschweißung lag natürlich sehr viel an der Temperatur, am Massenertrag der Förderung sowie an vielen physikalisch-chemischen Eigenschaften des pyroklastischen Materials.

Je größer die thermische Kapazität des Systems gewesen ist, ein um so größerer Teil der Tuffdecke unterlag einer *Wärmeverfestigung* (Zusammenkleben, Backen, Verschweißung, pneumatolytische Zementation), und ein um so geringerer Anteil fiel einer Wiederaufarbeitung zum Opfer. Einige »wurzellose« Partien (z. B. Cserépfalu, Kisgyőr) sind dermaßen verschweißt, daß sie bis heute als Rhyolithe gelten.

Eine gleichzeitig oder abwechselnd mit der Aschenstromtätigkeit vor sich gegangene normalvulkanische Tuffstreuung kann nicht außer acht gelassen werden. Natürlich ist eine Unterscheidung von lockeren (nicht verfestigten) Fluttuffen und Aschenregentuffen nur durch sorgfältige mikroskopische Untersuchung zu erzielen, die bei den meisten Tuffhorizonten noch aussteht.

Das Material der umgelagerten Tuffschichten sowie jenes der Tuffite ist mengenmäßig den ersten beiden Zufuhrmechanismen zuzuzählen. Ihre Bedeutung hängt von dem Lockerheitsgrad des primär angehäuften Tuffmaterials sowie von dem paläogeographischen Milieu, von der Dauer der vulkanischen Ruheperioden usw. ab.

Die ganze vulkanische Tätigkeit, welche die miozänen Tuffhorizonte erzeugt hat, kann nicht als ein den drei Hauptrhyolithtuffhorizonten entsprechender Vorgang aufgefaßt werden. Die unzähligen Pulsationen der Tuff-Förderung lassen sich für das ganze Gebiet nicht in diese drei voneinander

scharf getrennte und gleichzeitige Phasen einreihen. Es kann überhaupt nicht einwandfrei nachgewiesen werden, daß im Miozän eine größere Vulkanpause für das ganze Becken eingetreten wäre. Wir sind geneigt, die Kulminationen der vulkanischen Tätigkeit mit dem alten Begriff der »unteren«, »mittleren« und »oberen« Rhyolithtuffe in Zusammenhang zu bringen; in diesem Falle muß die Vorstellung von der strengen »Gleichzeitigkeit« der Tuffhorizontbildung fallen.

Der miozäne saure Vulkanismus der pannonischen »Zwischenmasse« spielte sich nicht überall in simultanen Paroxysmen ab, vielmehr traten wiederholte Belebungen der vulkanischen Tätigkeit mit größeren (relativen) Verzögerungen auf. Im allgemeinen müssen wir damit rechnen, daß sich die vulkanotektonisch einander entsprechenden Aktivitätsphasen ostwärts verspäten, daß sich also die äquivalenten vulkanischen Bildungen nach dieser Richtung hin verjüngen. Diese Verjüngung kann zeitlich recht erheblich sein, ja sie kann selbst Etagegrenzen überschreiten.

Diese allgemeine Tendenz läßt sich in ihren Einzelheiten auch folgendermaßen veranschaulichen: Es wird angenommen, daß sich die Kulmination der vulkanischen Aktivität wellenmäßig entlang der Leitstruktur — eines SW—NO streichenden Grabensystems — nach Nordosten fortpflanzt. So können die Ausbruchszentren (Spalten) schrittweise erweckt werden, die überholten dagegen erlöschen. Wenn von diesen Zentren aus ruckweise Tuffhorizonte aufgebaut werden, ist es bei einer so raschen und regional ausgedehnten Tuffproduktion, wie sie die Aschenströme darstellen, durchaus verständlich, daß sich die Ablagerungen benachbarter Ausbruchsstellen ineinander verzahnen; die älteren bilden nach Nordosten gerichtete Keile aus, die jüngeren nehmen an Mächtigkeit zu. So entsteht eine scheinbar gleichzeitige stratigraphische Einheit, die aber an beiden Enden chronologisch stark abweichende Lagerungsverhältnisse aufweist.

Um diese Betrachtungsweise zu untermauern, soll noch ein Umstand kurz erwähnt werden. Fluttuffe sind überall durch das Fehlen jeglicher Schichtung oder schichtenparallelen Absonderung gekennzeichnet. Daraus wurde geschlossen, daß diese Tuffe tatsächlich in »einem Ruck«, aus »einer Wolke« abgesetzt worden sind. So wurden recht unwahrscheinliche Mächtigkeiten (mehrere hundert Meter) als einaktige Bildungseinheiten angesehen. Die neuesten Resultate von BORDET—MARINELLI—MITTEMPERGHER—TAZIEFF (1963) vom »Sandstrom« im Tal der 10 000 Dämpfe brachten aber klare Beweise für die in zahlreichen Einzelabschnitten sich vollziehende Bildung von verhältnismäßig dünnen (~ 40 m) Fluttuffdecken. Die Abgrenzung der einzelnen Absätze verschwindet meist bei der Diagenese. Für diesen Anhäufungsmechanismus haben wir Beobachtungen auch im Tokajer Gebirge (Abaújszántó) (PANTÓ 1965). Es darf also letztlich nicht außer acht gelassen werden, daß nicht einmal Abkühlungseinheiten (*cooling units* von SMITH) vom einen

bis zum anderen Ende ganz simultaner Entstehung sein müssen und daß eine wesentliche Verjüngung auch ohne merkbare Gliederung eintreten kann.

Im folgenden sollen die einzelnen »Horizonte« kurz geschildert werden:

»*Unterer Rhyolithtuff*«

Die Verbreitung des »unteren Rhyolithtuffs« beschränkt sich nach der von uns vorgeschlagenen Definition auf Mittel-Oberungarn (südlich und nördlich von der Mátra und dem Bükk-Gebirge). Sein wichtigstes Charakteristikum ist seine unmittelbare Überlagerung — oft auch Wechsellagerung — über oder mit den roten terrestrischen Tonen, die das unterste Miozän vertreten. Entsprechend setzt der miozäne saure Vulkanismus mit dem Emporsteigen dieses Tuffmaterials ein. Die Bildung dieses ziemlich charakteristischen, echt rhyodazitischen, grobkörnigen, glasig-kristallinen Fluttuffes endet noch im Untermiozän. Es dürfen ihm also mittelmiozäne Tuffbildungen nicht einmal beim Fehlen sedimentärer Zwischenlagerungen angegliedert werden. Die Durchschnittsmächtigkeit beträgt etwa 80 m.

Die Hauptmasse dieses Fluttuffs ist locker oder leicht verschweißt, aber es gibt auch Beispiele für starke, mit partieller Wiederaufschmelzung verbundene Verschweißungen, deren Produkte als Rhyolith bezeichnet werden (Demjén, Kisgyőr). Im Tuffmaterial — sowohl in der Grundmasse als auch in den Bimssteinbrocken — überwiegt das Glas. Die Menge der Fenokristalle ist recht niedrig (10—15%), Plagioklas, K-Feldspat, Biotit und Quarz. Aschenregentuffe, umgelagerte Tuffe und Tuffite begleiten den Fluttuffkomplex in variierenden Mengenverhältnissen und Verteilungsarten.

»*Mittlerer Rhyolithtuff*«

Wenn wir aus dem »unteren« Rhyolithtuff eine wohl definierte Kategorie und ein stratigraphisch gut auswertbares Niveau schaffen wollen, so geschieht das auf Kosten der Reinheit und Klarheit des begrifflichen Inhaltes des »mittleren« Rhyolithtuffs. In ihm müssen wir eingentlich alle sauren Tuffbildungen des ungarischen Mittelmiozäns zusammenfassen.

Wir wollen nicht behaupten, daß die Bildungszeit der als »mittlerer« Rhyolithtuff bezeichneten Tuffschichten die ganze Zeitspanne vom unteren Helvet bis zum obersten Torton (Ende des Bugloviens) ausfüllt. Liegend- und Hangendverhältnisse lassen aber keine nähere Einengung der Bildungszeit zu. Die Verbreitung ist, von der südwestlichen Staatsgrenze angefangen bis zur Nordspitze des Tokajer Gebirges, die größte unter allen Horizonten. Eine Verjüngung der Aktivität von SW gegen NO ist unter den hierher eingereihten Tuffgliedern klar erkennbar.

Obwohl die so weit gefaßte Umgrenzung des »mittleren Rhyolithtuffs« eine große Fülle von Tuffbildungen enthält, die voneinander in Zusammensetzung, Fazies und Bildungszeit ziemlich entfernt sind, können wir doch nicht behaupten, daß diese durch klare Lagerungsverhältnisse von den älteren und jüngeren Tuffen scharf abgesondert wären. Das hat auch BALOGH dazu gezwungen, bei der Redaktion des 1 : 200 000 Blattes »Eger« Sammelkategorien für den vom »unteren« und für den vom »oberen« untrennbaren »mittleren«

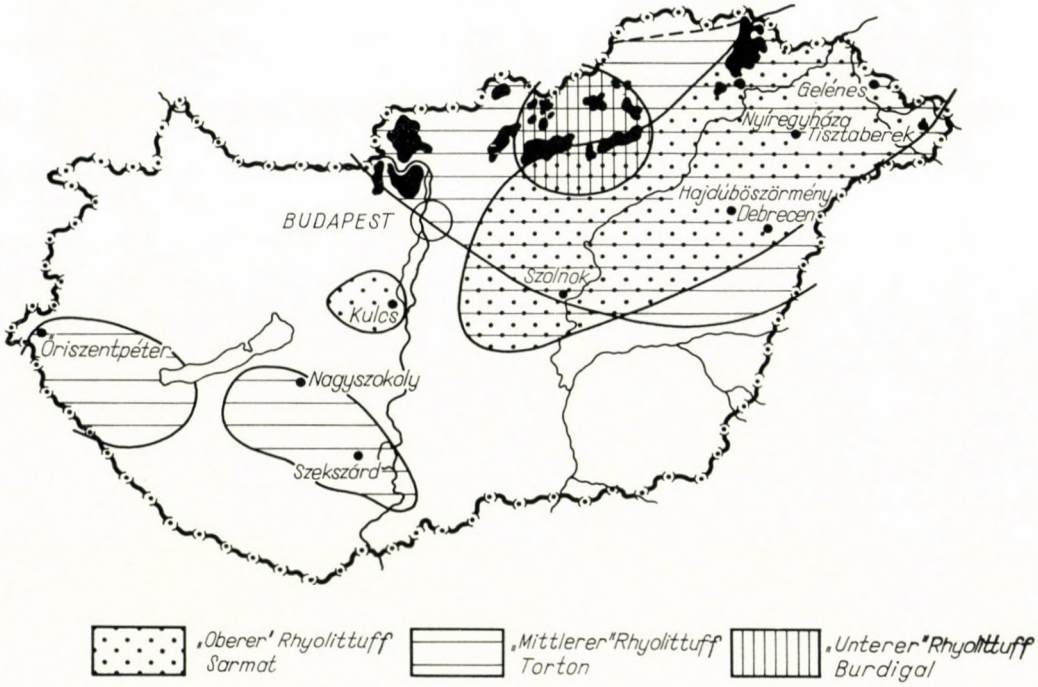

Abb. 1

Rhyolithtuff aufzustellen. Diese Schwierigkeiten sind besonders in der Nähe der Ausbruchszentren (Süd-Mátra, Südraum der Bükk, Tiefbohrung von Nyíregyháza, Gelénes) am größten. Die Durchschnittmächtigkeit des »mittleren« Rhyolithtuffs beträgt ungefähr 450 m.

Die dem »mittleren« Rhyolithtuff hinzugezählten Tuffbildungen lassen sich — selbst vorausgesetzt, daß »untere« und »obere« Tuffe nicht darunter stecken — allgemein kaum charakterisieren. Ihrer chemischen und mineralogischen Zusammensetzung nach sind sie eher Rhyodazite und Dazite als echte Rhyolithe. An Fazies kommen darunter unregelmäßig in Verteilung und Mengenverhältnis alle erwähnten Typen vor. Die das reinste Eruptivmaterial vertretenden Fluttuffe sind glasig-kristalline, manchmal kristallin-glasige Tuffe. Der Grad der Verschweißung ist in manchen Zügen recht hoch (»Dazite«).

Unter den Fenokristallen, die 10—30% ausmachen, überwiegen die Plagioklase, während K-Feldspat und Quarz eine untergeordnete Rolle spielen. Femische Gemengeteile sind durch Biotit, Amfibol und Pyroxen vertreten.

»Oberer Rhyolithtuff«

Die höchsten und jüngsten Tuffschichten des ungarischen Miozäns werden in dieser Gruppe zusammengefaßt. Die untere Grenze ist »theoretisch« scharf an die Basis des Sarmats gesetzt. Praktisch ist sie nur durch Sedimenteinlagerungen erfaßbar. Die obere Grenze ist wegen des Hiatus im Unterpliozän nicht einmal theoretisch eindeutig: sie kann wohl bis zum Oberpliozän (Oberpannon) hinaufreichen.

Die Verteilung beschränkt sich auf Mittel- und Nordostungarn. Die Mächtigkeit nimmt nordostwärts stark zu. Sie beträgt im Durchschnitt etwa 350 m.

Die Zusammensetzung schwankt zwischen Rhyodazit und Rhyolith. Fluttuff — stark verschweißt — überwiegt besonders an Stellen der großen Mächtigkeitszunahme. Glasiges Material ist in großem Überschuß vorhanden. Unter den Fenokristallen ($< 15\%$) nähert sich die Menge von K-Feldspat jener der Plagioklase. Biotit und Quarz sind von untergeordneter Bedeutung.

LITERATUR

1. Balogh, K.: Erläuterungen zur geologischen Karte Ungarns 1 : 200 000, Blatt Eger. 1963. (In Vorbereitung). — 2. Bordet, P.—Marinelli, G.—Mittempergher, M.—Tazieff, H.: Contribution à l'étude volcanologique du Katmai et de la Vallée des Dix Mille Fumées (Alaska). Soc. belge de Géol. Pal. Hydr. Mémoires in **8** N° 7, 1—114, 1963. — 3. Gyarmati, P.: Földtani Közlöny **91,** 374—381, 1961. — 4. Marfunin, A. S.: Mineralogical Magazin **33,** 12, 298—314, 1962. — 5. Pantó, G.: Acta Geologica. Acad. Sci. Hung. **6,** 307—331, 1962. — 6. Richthofen, F.: Jahrb. k. k. Geol. Reichsanst. **2,** 153—278, 1861. — 7. Szádeczky-Kardoss, E.: A kárpáti közbenső tömeg magmás mechanizmusáról (On the mechanism of magmatic activity in the Carpathians). MTA Geokémiai Konferencia Kiadványai II. 1959. — 8. Szádeczky, Gy.: Pótfüzetek a Term.-tud. Közlönyhöz, **22,** 71—77, 1890. — 9. Szádeczky- Gy.: Amphibolandesittuffe in der SW-lichen Hälfte des siebenbürgischen Beckens. Múzeumi Füzetek **I,** 2, 176—190, 1912. — 10. Szádeczky-K., Gy.: Tuffstudien in Siebenbürgen. Múzeumi Füzetek **I,** 2/2, 295—333, 1913, **II,** 3/2, 233—292, 1914, **III,** 4/1, 105—213, 1916, **IV,** 1917.—11. Székyné-Fux, V.: Földtani Közlöny, **87,** 63—68, 1957. — 12. Zelenka, T.: Földtani Közlöny 94. 33—52. 1964.

MIOCENE TUFF HORIZONS OF HUNGARY

By

G. Pantó

Abstract

The most significant phenomena in the history of Tertiary volcanism in Hungary are the extensive flood-tuff covers (6—40 000 km²). They represent special mass-productions of near-surface development of the Pannonian Massif, with their bulk in the ignimbritic (welded tuff) domain. On account of their large extension and comparatively short period of development, they have a special stratigraphic significance surpassing all of the other pyroclastics of the Carpathian Basin.

Their long-accepted denominations are: "lower rhyolite tuff" (Burdigalian), "middle rhyolite tuff" (Tortonian) and "upper rhyolite tuff" (Sarmatian). The mineralogical-chemical composition of the variable tuff complex of a thickness frequently exceeding 1000 m varies around plagioclase-rhyolitic-plagioclase dacite.

ГОРИЗОНТЫ МИОЦЕНОВЫХ ТУФОВ В ВЕНГРИИ

Г. ПАНТО

Резюме

Важнейшими свидетелями третичного вулканизма Венгрии являются широко распространенные (от 6 до 40 тысяч км²) покровы туфов. Они представляют собой образовавшиеся в приповерхностной зоне массовые продукты Паннонского массива, ядро которых находится в игнимбритовом поле (представленном спекшимися туфами). Благодаря широкому распространению и ограниченной продолжительности образования этих туфов, они имеют особенно важное стратиграфическое значение, превосходящее в таком отношении все другие пирокластиты Карпатского бассейна.

Для рассматриваемых образований уже давно приняты названиа — «нижние» риолитовые туфы (бурдигаль), «средние» риолитовые туфы (тортон) и «верхние» риолитовые туфы (сармат). Минералогическо-химический состав пестрых туфовых толщ, мощность которых часто превышает 1000 м, колеблется на пределе между (плагиоклазовым) риолитовым и дацитовым составами.

ON THE INDIVIDUAL PROPERTIES OF SOME HUNGARIAN ZEOLITES

By

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Amongst the zeolites occurring in the andesites and the basalts of Hungary, the chabasite of the Dunabogdány and Szob andesites, the desmite of Dunabogdány and the natrolite of the Gulács and Uzsabánya basalts, resp. were studied and compared with similar occurrences of zeolites from abroad.

The "zeolite water" contained in our chabasites — as well as that in the chabasites from abroad — falls under two heads. Some of it is in a weak bond and is expelled below 220 degrees centigrade. The rest is adsorbed water in stronger bond and is expelled at relatively higher temperatures. In the structure of the chabasite from Dunabogdány, water plays a more important role than in the rest of the chabasites, in accord with its different origin. Chabasite structure undergoes no change up to 560 degrees centigrade. At 1000 degrees chabasite from Dunabogdány was found to turn into anorthite, that from Szob into anorthite plus barbierite, and that from Strzegom into a plagioclase felspar between anorthite and bytownite plus some orthoclase (1.67 per cent K_2O !), respectively.

The "zeolite water" of desmite is an essential constituent of the structure, playing presumably a role in holding together the layers of the structure. Desmite turns at 250 degrees centigrade into heulandite plus wairikite or clinoptylolite. At 400 degrees a desmite exhibiting very few lines turns up again in the X-ray pattern. At 1000 degrees the final stage consisting of anorthite is reached.

The "zeolite water" of natrolite is partly of the crystal water type, partly adsorbed water, playing an essential role in holding together the chains. Some of the water occurring in very strong bond stays in the lattice even if the mineral is heated to 500 degrees centigrade. At 560 degrees natrolite turns into alpha carnegieite plus nepheline, at 680 degrees into nepheline plus albite, at 1000 degrees into nepheline.

As a result of the petrochemical features peculiar to Hungarian basalts, the natrolites derived from them contain more Ca^{++} and water and are characterized by a more copious Al—Si substitution than other natrolites.

In the course of a series of complex investigations of zeolites the author has studied the zeolites occurring in Hungarian andesites and basalts, comparing them with zeolites found in similar as well as different rocks from abroad.

For each one of the three main groups of zeolites a representative species has been chosen as follows: chabasite, from andesites of the localities Dunabogdány and Szob in Hungary and from a pegmatitic cavity at Strzegom (Poland); desmite, from andesites of Dunabogdány and Nadap in Hungary and from a pegmatite of Strzegom; and finally natrolite, from basalts of Gulács and Uzsabánya in Hungary, from Fassa Valley (Tirol) and Langesund-Fjord (Norway), respectively.

Investigations were started with recording DTA graphs. In this manner the end temperature of the exo- and endothermic reactions undergone by the substances could be established. As a next step, samples were heated at the end temperatures in question and then subjected

a) to X-ray analysis and X-ray diffractometry in order to establish changes in structure;*

b) to water loss measurements by the dehydration method on the one hand and by the devolatilization method in a current of air, introduced by SZÁDECZKY-KARDOSS, on the other;

c) to infra-red spectroscopy in order to clear up the bond types in which water occurs.**

Weight loss was also determined after heating to 560 and 1000 degrees C. respectively.

The chemical composition was determined by wet analysis completed by spectroscopic methods.***

Finally, in order to establish the regenerative capabilities of the samples, the SZÁDECZKY—SIMÓ method was employed with some modifications. This consisted essentially in heating the samples all day at a given temperature and measuring the weight loss every two hours, and in placing them for the night above the water-level in a half-filled exsiccator vessel (that is, under a water vapour tension of approximately 100 per cent) and determining the weight increase in the morning. This was continued until a constant weight was attained after repeated de- and rehydration. The procedure was repeated at temperature intervals of 50 degrees.

The DTA graph of *chabasite* features an endothermic peak at 200 degrees C. ending at 400 degrees C. and a sharp exothermic peak between 750 and 850 degrees C., in agreement with literature. (Fig. 1 a, b, c.) On the graph of the chabasite from Strzegom there also occurred a lowertemperature endothermic reaction ending at 150 degrees C.

The Debye—Scherrer patterns were recorded on unheated samples and on samples heated at 170, 290, 400, 500, 560 and 1000 degrees C., resp., until the weight remained constant. As a result it can be stated that the chabasite structure undergoes no essential change in the course of the expulsion of water. However, the d/hkl values obtained were found to decrease monotonously with increasing loss of water, in agreement with SMITH's results

* X-ray diffractometry examinations were conducted in the Geochemical Research Laboratory of the Hungarian Academy of Sciences, Debye-Scherrer patterns were recorded at the Mineralogical Institute of Eötvös University, Budapest. Thanks are due to I. FÜRST and Mrs. G. GYÖRE for the preparations.

** Infrared spectrograms were taken in the Infrared Spectroscopy Laboratory of the Institute of Organic Chemistry, Eötvös University, Budapest. Thanks are extended to F. RUFF for having prepared the records.

*** For the preparation and evaluation of the spectroscopic records the author expresses her gratitude to I. KUBOVICS.

[35] who observed a decrease of lattice spacing in dehydrated chabasite. COOMBS [5] found that chabasite when heated at 250 degrees C. turned into phillipsite plus wairikite. This transformation was observed on Dunabogdány chabasite heated to 170 degrees C. or above, although the chabasite lines were still present. There exists, however, the possibility that a retransformation took place on cooling. The exothermic peak at 700 to 800 degrees centigrade indicates, on the other hand, a complete rearranging of the lattice, the formation of new mineral phases. The author found the end product of this

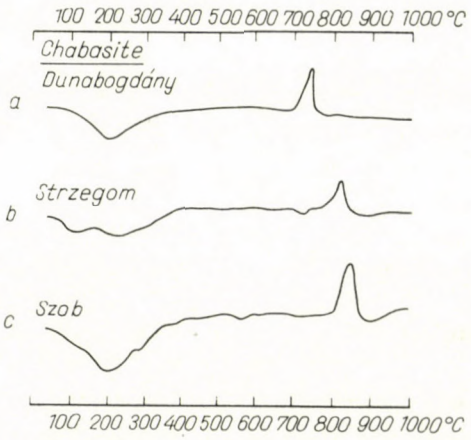

Fig. 1. DTA graphs of chabasites. *a)* Dunabogdány, *b)* Strzegom, *c)* Szob

process to depend on the locality of origin of the samples studied. The Strzegom chabasite, containing as much as 1.67 per cent potash, turned into a plagioclase intermediate between anorthite and bytownite, plus orthoclase, the Szob chabasite into barbierite containing 0.54 per cent soda, the Dunabogdány mineral into anorthite. However, in this last instance some very diffuse lines still indicate the presence of chabasite after heating to 1000 degrees, under a further decrease of the d/hkl values. All this suggests that either the lattice of chabasite from Dunabogdány is not fully transformed into phillipsite plus wairikite at 250 degrees C. or the transformed part subsequently assumes the more stable dehydrated chabasite configuration. At 700 to 800 degrees C. the lines become diffuse, the lattice begins to break down. As a result, part of the mineral is turned into anorthite whereas some of it presumably becomes roentgenographically amorphous. This latter hypothesis is confirmed by the fact that neither quartz, nor any sodium mineral could be demonstrated although that would have been expected considering the soda content of the Dunabogdány sample, higher than that of the Szob mineral. The d/hkl values of the Dunabogdány chabasite, still present at fairly high temperatures,

reveals a considerable stability of lattice. On the other hand, irrespective of the locality of origin, the d/hkl of 3.216—3.222(ms) pre-eminently characteristic of felspars showed up in every sample heated above 170 degrees C., a fact that suggests the transformation into felspar to commence very early (Tabl. 1).

Table 1

Chemical analyses of chabasites
(Dr. B. Simó, analyst)

	Dunabogdány	Strzegom/Poland/	Szob
	per cent		
SiO_2	49.69	48.68	48.45 (48.42)
TiO_2	—	—	—
Al_2O_3	18.65	18.00	18.15
Total iron	0.15	1.43	0.13
MnO	—	—	—
MgO	0.20 (0.02)	0.81	—
CaO	9.00	8.43	10.59
Na_2O	0.97	0.25	0.54
K_2O	0.33	1.67	0.23
Total water	20.99	20.25 (20.61)	20.25
P_2O_5	—	—	—
	99.98	99.52	98.34

The results of chemical analysis of Dunabogdány chabasite as stated in literature [27, 29] do not differ substantially from those obtained in the present study. Slight differences are restricted to silica and water content.

Analysis revealed the trace elements contained in Dunabogdány and those in Szob chabasite to be identical whereas Strzegom chabasite also featured Fe, K, Mg, Sr, Ba, Ag, Mn an Pb (Table 10). Calculating from the results of the chemical analysis the composition of our chabasites for a water-free basis with 12 O_2, we have

Dunabogdány: $Na_{0.155}K_{0.036}Ca_{0.805}Mg_{0.023}$ $Al_{1.838}Fe_{0.006}Si_{4.152}O_{12}$
Szob: $Na_{0.088}K_{0.020}Ca_{0.961}$ $Al_{1.815}Fe_{0.008}Si_{4.152}O_{12}$
Strzegom: $Na_{0.040}K_{0.177}Ca_{0.710}Mg_{0.100}$ $Al_{1.789}Fe_{0.088}Si_{4.106}O_{12}$

Taking into consideration also the water content, the composition becomes

Dunabogdány: $Na_{0.156}K_{0.036}Ca_{0.814}Mg_{0.024}$ $Al_{1.856}Fe_{0.008}Si_{4.193}O_{12} \cdot 5.881\ H_2O$
Szob: $Na_{0.089}K_{0.020}Ca_{0.975}$ $Al_{1.841}Fe_{0.008}Si_{4.184}O_{12} \cdot 5.823\ H_2O$
Strzegom: $Na_{0.041}K_{0.180}Ca_{0.773}Mg_{0.102}$ $Al_{1.820}Fe_{0.090}Si_{4.176}O_{12} \cdot 5.795\ H_2O$

Infrared spectrography was applied to zeolites by several workers. [24, 31, 28.] The present author has, however, no knowledge of this technique ever having been applied to heated zeolites. On the graphs taken of natural-state and heated chabasites, shown as Fig. 2, the bands covering the interval between 3000 and 3620 cm^{-1} and the band at 1640 cm^{-1} are due to

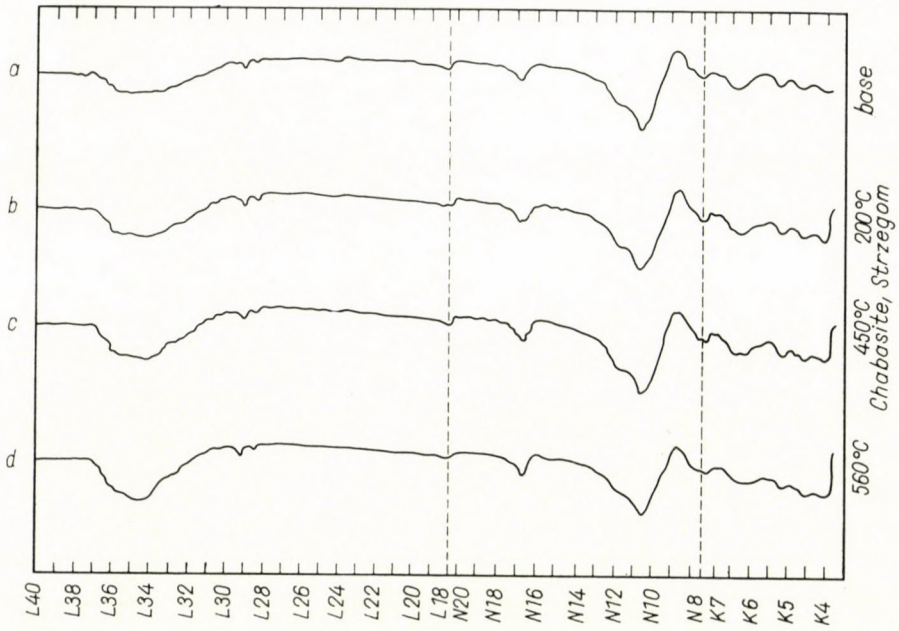

Fig. 2. Infrared spectrograms of Strzegom chabasite. *a)* natural state, *b)* after heating at 200, *c)* at 450, *d)* at 560 degrees C.

the presence of water, whereas the band at 1020 cm^{-1} corresponds to the frequency of the $Si-O-Al^{[4]}$ bond. The absorption bands between 400 and 700 cm^{-1} are due to the oscillation of cations built into the lattice [24].

Heating changes the adsorption bands due to water. Even at 200 degrees C. the band beginning at 3270 cm^{-1} is displaced towards 3300 cm^{-1} and the effect is further enhanced by heating to higher temperatures. On our samples heated above 560 degrees C. the band at 3620 cm^{-1} is repressed whereas the bands due to the silicate bond are present even at higher temperatures.

The experiments of dehydration and devolatilization provide insight into the process of water loss in chabasite. The author's results agree as to water content with the data recorded in literature [14, 15, 16], but the process of water loss itself presented certain modifications in function of the locality of origin. This is apparent in the water loss curves obtained with the two techniques applied (Fig. 3, c_1, c_2, Tabl. 2).

Table 2

Determination of water content of chabasites by dehydration

Temperature degrees C.	Percentage, weight loss on heating		
	Dunabogdány	Strzegom	Szob
170	9.90	12.49	11.16
290	14.25	17.36	15.82
400	16.20	17.90	17.14
480	16.25	—	17.14
Total weight loss after heating for two hours, in per cent			
560	18.35	17.85	—
Total weight loss by PENFIELD'S method in per cent			
1100	20.89	20.25	20.25

Up to 220 degrees C., chabasite loses about three quarters of its water content. The major part of the remaining water escapes up to 300 degrees and very little water is left at 560 degrees.

The devolatilization method generally yields higher values than the dehydration method (see Fig. 3 b, Tabl. 3).

From the point of view of the process of dehydration (Fig. 3 a), the Dunabogdány chabasite presents the anomaly of the escape of a large amount of water at a higher temperature. This is presumably due to the fact

Table 3

Weight loss as determined by the devolatilization method, in per cent, after heating for two hours

Temperature degrees C	Dunabogdány	Strzegom	Szob
220	16.97	16.90	14.85
From 220 to 570	5.82	3.71	5.23
Total	22.79	20.61	20.08

that in Dunabogdány andesite, in the lava pouring on top of an Oligocene clay surface, and in the chabasite formed in the lava, water tension was higher in accordance with the principle of transvaporisation [37] than e.g. in a pegmatitic cavity. Water loss occurring at a high temperature suggests that in chabasite "adsorbed water" may occur in a very strong bond, presumably on the surfaces of the internal cavities of the lattice.

Studies concerning the regeneration of the samples have shown that after heating to 200 degrees C. the Szob and Dunabogdány chabasites readsorb the full amount of water lost whereas Strzegom chabasite recovers from 2 to 3 per cent less than its original water content. Between 400 and 500 degrees

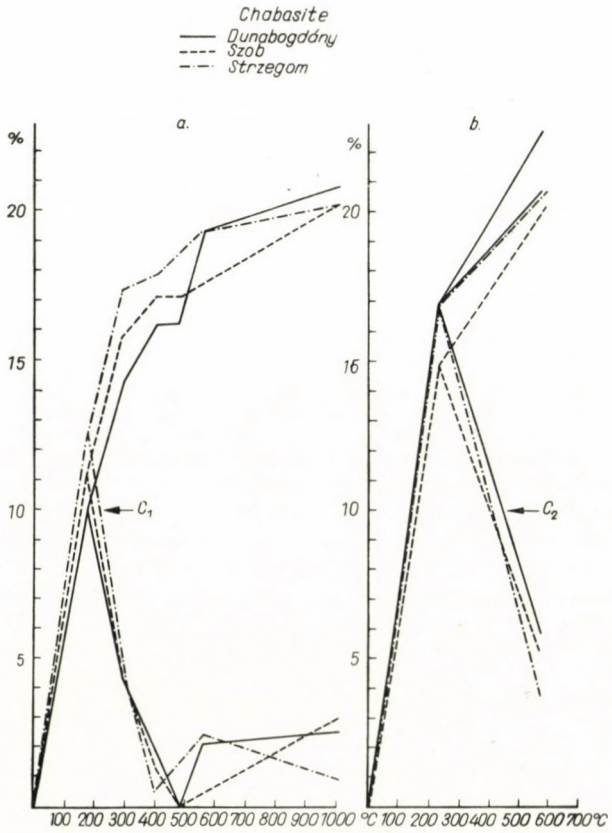

Fig. 3. Dehydration (*a*), devolatilization (*b*) and weight loss graphs of chabasite (c_1 — weigh loss on dehydration, c_2 — on devolatilization)

only the samples from Dunabogdány shows a full recovery, the Szob and Strzegom samples readsorb from 5 to 8 per cent less. This is another argument in favour of the hypothesis that water bond is stronger in the lattice of the mineral from Dunabogdány than in the others. Heating above 500 to 560 degrees diminishes considerably the intake of water (Fig. 4).

The evaluation of all the above results shows in agreement with SMITH [34] that "zeolite water" in chabasite is of two kinds. One kind escapes below 220 degrees C., presenting a peak at 150 degrees C. on some DTA graphs and

a band of absorption beginning at 3270 cm^{-1} on the infrared spectrogram. It exhibits no basic p_H when removed by devolatilization under 200 degrees C. The other kind which, in the author's opinion, connects the Ca cation

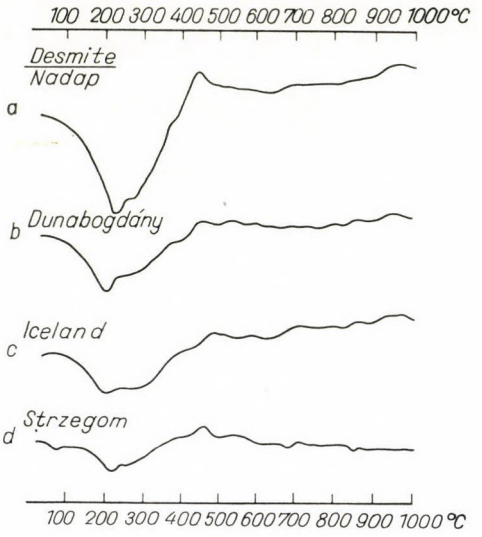

Fig. 5. DTA graphs of desmites. *a)* Nadap, *b)* Iceland, *c)* Dunabogdány, *d)* Strzegom

with a hydrogen bridge bond to the lattice and is to be regarded according to ROZHKOVA et al. [28] as the water of co-ordination around Ca, leaves the lattice gradually above 200 degrees C. At 560 degrees it still holds a well-defined position (see the infrared spectrogram of the sample heated at 560 degrees). The chabasite lattice does not change substantially even when its entire water content is removed.

From a practical point of view chabasite and related zeolites can be regenerated indefinitely between 100 and 400 degrees C. and to a fairly high degree up to 500 degrees C. Among the Hungarian chabasites that of Dunabogdány exhibits a stronger bond of water and a better ability to regenerate than that of Szob.

The DTA graphs of our *desmite* samples exhibit a depression indicative of an endothermic process between 50 and 400 degrees centigrade. Superimposed on this, there occur sharper endothermic peaks at 230 degrees and at 280 to 300 degrees C. on the one hand and an exothermic one ranging from 430 to 480 degrees C. (Fig. 5 a, b, c, d).

X-ray patterns have been recorded on the original material and also when the samples were heated to 250, 300, 400, 500, 560 and 1000 degrees C.

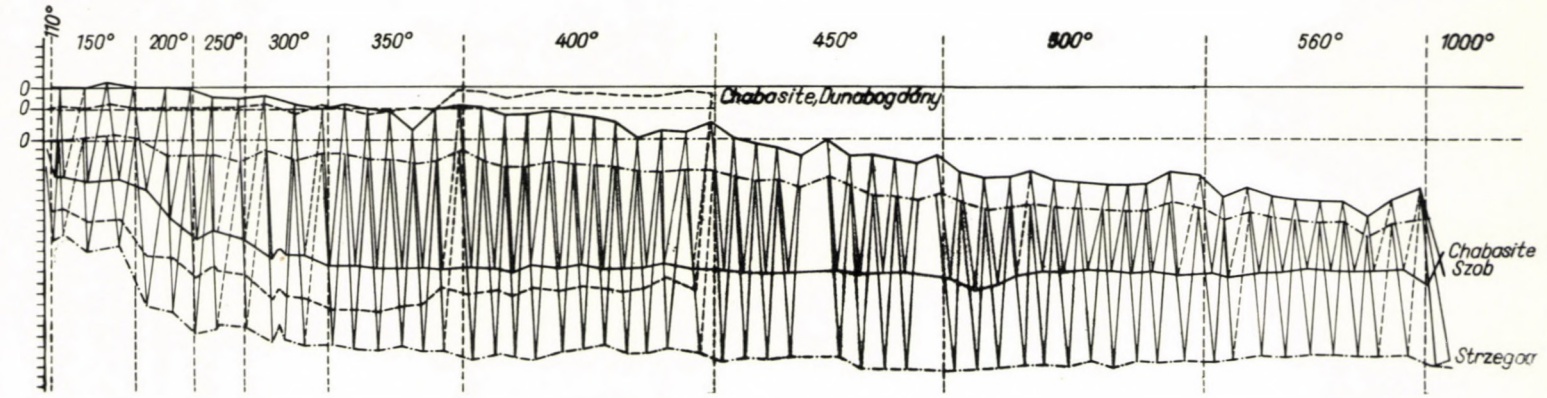

Fig. 4. Regeneration graphs of chabasites

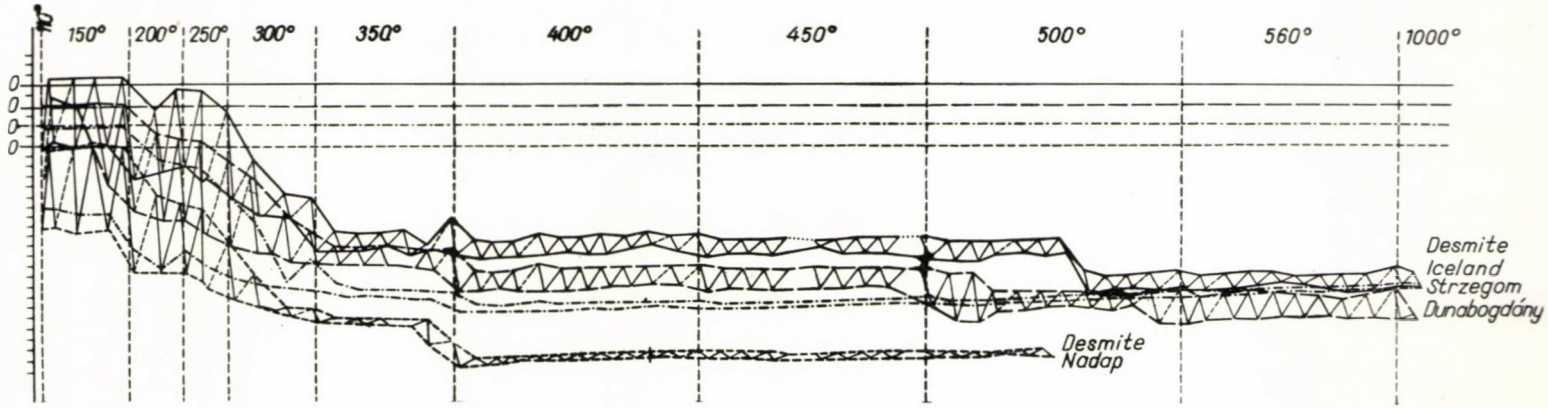

Fig. 8. Regeneration graphs of desmites

respectively. The d/hkl values of the original material agree fairly well with the data found in literature. Heating decreases the number of lines and causes a gradual diffusion of those that remain. The minimum of lines is obtained after heating to 400 degrees (500 degrees in the case of the Dunabogdány mineral). According to COOMBS [5] desmite turns into epistilbite plus wairikite at 250 degrees C. Our samples have revealed besides the d/hkl values of desmite also the lines of further decomposition products, namely, heulandite plus wairikite in the case of the Nadap and Dunabogdány samples, clinoptylolite in the case of the Iceland and Strzegom ones, with some d/hkl values of wairikite still recognizable on the Iceland sample. It is further to be noted that the 4.03 to 4.08/100/line of desmite is split above 250 degrees C. in two (3.94 to 3.96 and 4.28 to 4.33, both strong), (Table 4).

The results of the chemical analyses reveal that although all samples contain some potash, those of Strzegom and Nadap contain more than the other two. In the first case the excess potash presumably derives from the pegmatitic medium, in the second from the granitic country rock in which the desmite-bearing andesite dyke occurs (Tabl. 5).

Investigation of the trace elements showed magnesium to be present in all samples, strontium in the Hungarian samples and in the Strzegom mineral, iron in the sample from Nadap, titanium in the Dunabogdány and Iceland samples, manganese and gallium in the Dunabogdány sample (Table 10).

Reduced to 18 O_2 and the water-free state, the chemical composition of the samples studied, is as follows:

Nadap: $Na_{0.271}K_{0.035}Ca_{1.000}Ti_{0.003}Al_{2.465}Si_{6.567}O_{18}$
Dunabogdány: $Na_{0.255}K_{0.018}Ca_{1.179}Fe_{0.047}Al_{2.887}Si_{6.516}O_{18}$
Iceland: $Na_{0.387}K_{0.006}Ca_{1.086}Al_{2.433}Si_{6.536}O_{18}$
Strzegom: $Na_{0.229}K_{0.041}Ca_{1.005}Fe_{0.041}Al_{2.370}Si_{6.621}O_{18}$

Considering also the water content we have, in the same order as above:

$Na_{0.267}K_{0\,035}Ca_{0.997}\ Al_{2.429}Ti_{0.003}\ Si_{6.472}O_{18} \cdot 7.260\ H_2O$
$Na_{0.255}K_{0.018}Ca_{1.179}\ Al_{2.344}Fe_{0.047}Si_{6.397}O_{18} \cdot 7.328\ H_2O$
$Na_{0.375}K_{0.006}Ca_{1.079}\ Al_{2.418}\ Si_{6.496}O_{18} \cdot 7.112\ H_2O$
$Na_{0.227}K_{0.041}Ca_{0.995}\ Al_{2.347}Fe_{0.040}Si_{6.557}O_{18} \cdot 7.174\ H_2O$

The infrared spectrograms of the investigated desmites coincide with the ones given in literature. Absorption in the 3520 to 3620 and 3200 to 3300 cm^{-1} range turned out to be stronger than for any other zeolite species (Fig. 6). Of the spectrograms of heated samples, the one taken after heating at 200 degrees C. exhibits a weakening of the water bands except for that at 3620 cm^{-1}. After heating at 360 degrees all water bands disappear and those due to

Table 4

Further alterations of desmite

Locality	250	300	1000
	degrees centigrade		
Dunabogdány	desmite heulandite wairikite	desmite heulandite wairikite	anorthite
Nadap	desmite heulandite wairikite	desmite heulandite	anorthite
Iceland	desmite clinoptylolite (wairikite)	desmite clinoptylolite	—
Strzegom	desmite clinoptylolite	desmite clinoptylolite	anorthite orthoclase

the Si—O bond at 400 to 1300 cm^{-1} also shift slightly. Consequently, the escape of water entails a change in structure. According to YUKHNEVICH and FEDOSEEV [12] the infrared spectrogram of desmite suggests, similarly to that of chabasite, an adsorptive-type bonding of water.

Table 5

Results of chemical analysis of desmites
(Dr. B. SIMÓ, analyst)

	Nadap	Dunabogdány	Iceland	Strzegom
	per cent	per cent	per cent	per cent
SiO_2	55.06	53.87	54.74	55.48
TiO_2	0.04	—	—	—
Al_2O_3	17.53	16.75	17.30	16.85
Total iron	—	0.51	—	0.45
MnO	—	—	—	—
MgO	—	—	—	—
CaO	7.93	9.10	8.48	7.85
Na_2O	1.17	1.09	1.64	0.99
K_2O	0.25	0.11	0.04	0.29
Total water	18.50	18.49	17.95	18.19
P_2O_5	—	—	—	—
	100.48	99.92	100.15	100.10

On dehydration every sample studied lost a large part, up to 16 per cent, of its water content on heating to 250 degrees C. The rest escaped gradually up to 560 degrees C. (Fig. 7), (Tabl. 6).

Devolatilization already results at 300 degrees C. in an almost complete loss of water. The rest, 1 to 2 per cent, is removed below 560 degrees C. (Fig.

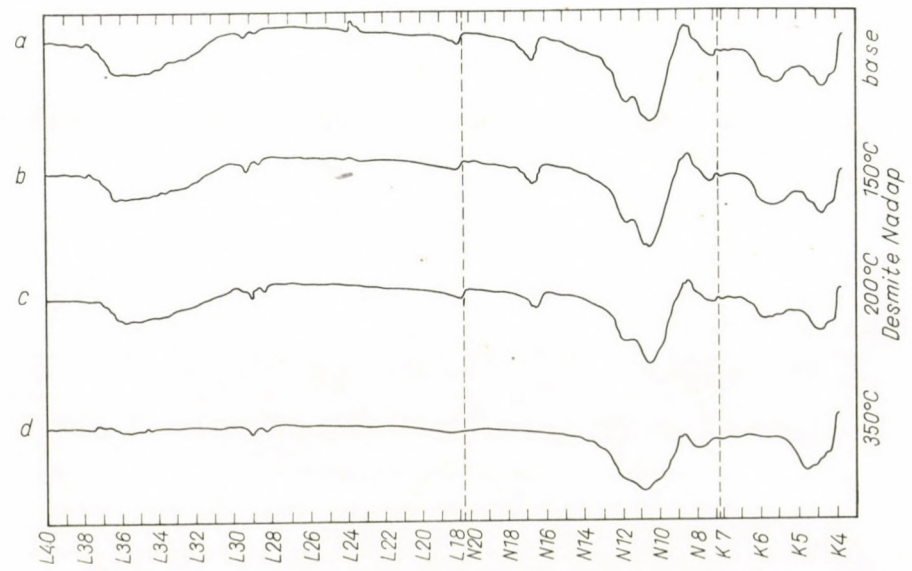

Fig. 6. Infrared spectrograms of desmite from Nadap. *a)* natural state, *b)* after heating at 150, *c)* at 200, *d)* at 350 degrees C

7 b). The desmite from Dunabogdány contains more water and preserves more of it at higher temperatures than the rest (Tabl. 7).

The water losses established at different temperatures are listed in the table below (see also Fig. 7, c_1, c_2, Table 8).

Examination of the regenerating ability of desmites showed that the samples heated to 150 degrees C. fully regenerate, sometimes taking in more water than it contained originally (Dunabogdány, Iceland). The desmites from Nadap and Strzegom fail to regenerate when heated above 350 degrees C. The only sample capable of recovering water after heating above 560 degrees is that of Dunabogdány, and even in that case recovery is as little as 2 to 2.5 per cent (Fig. 8).

WYART [44], TAYLOR [40] and HEY and BANNISTER [10] state the water present in the cavities of the desmite lattice to be reversibly displaceable rather than being bound to rigorously fixed positions. Infrared spectroscopy, X-ray

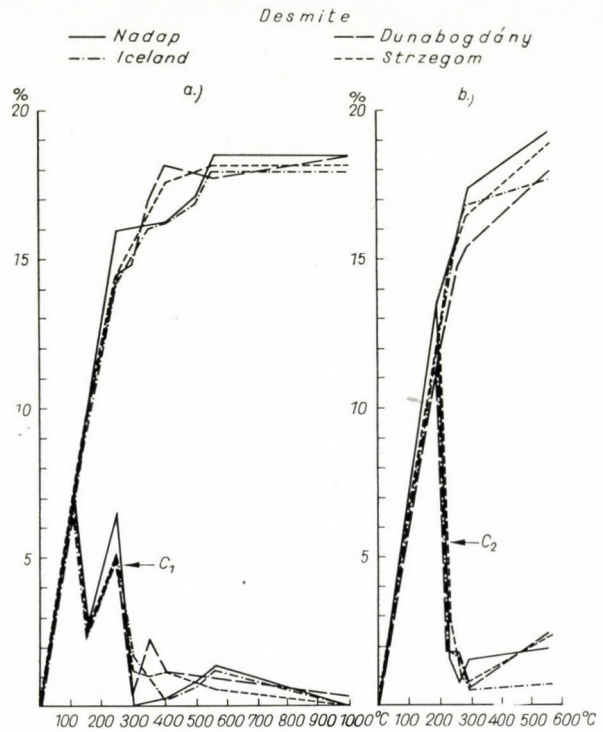

Fig. 7. Dehydration (*a*), devolatilization (*b*) and weight loss graphs of desmites (c_1 — weight loss on dehydration, c_2 — on devolatilization)

Table 6

Water loss on heating, in per cent

Temperature degrees C.	Nadap	Dunabogdány	Iceland	Strzegom
110	7.09	7.15	7.05	7.03
150	9.51	9.61	9.44	9.38
250	15.96	14.47	14.28	14.24
300	16.01	14.84	—	15.41
350	—	16.99	16.02	16.43
400	16.27	18.17	16.22	17.57
500	17.13	—	16.92	—
Total weight loss after heating for two hours, in per cent				
560	18.50	17.74	17.94	18.15
Total weight loss by PENFIELD'S *method in per cent*				
1100	18.50	18.49	17.95	18.19

Table 7

Weight loss as determined by devolatilization in per cent, for two hours

Temperature degrees C.	Nadap	Dunabogdány	Iceland	Strzegom
190	13.34	11.47	12.53	11.60
190 to 230	1.63	1.77	1.81	2.88
230 to 260	0.84	1.62	1.84	1.20
260 to 290	1.55	0.57	0.67	0.80
290 to 550	1.91	2.40	0.79	2.27

and DTA data concur in proving that the change of the desmite lattice commences at about 400 degrees C. Most of the water is expelled below that temperature and also the restoration of the water content is restricted to lower

Table 8

Temperature interval degrees C	Nadap		Dunabogdány		Iceland		Strzegom	
	dehyd.	devol.	dehyd.	devol.	dehyd.	devol.	dehyd.	devol.
	water loss in per cent between the temperature limits cited							
110	7.09	—	7.15	—	7.05	—	7.03	—
110—150	2.42	—	2.46	—	2.39	—	2.35	—
0—190	—	13.34	—	11.47	—	12.53	—	11.60
190—230	—	1.63	—	1.77	—	1.81	—	2.88
150—250	6.45	—	4.86	—	4.84	—	4.86	—
230—260	—	0.84	—	1.62	—	1.84	—	1.20
260—290	—	1.55	—	0.57	—	0.67	—	0.80
250—300	0.05	—	0.37	—	1.74	—	1.17	—
300—350	0.26	—	2.15	—	—	—	1.02	—
350—400		—	1.18	—	0.20	—	1.14	—
400—500	0.86	—	—	—	0.70	—	—	—
500—560	1.37	—	—	—	1.02	—	0.58	—
250—550	—	1.91	—	2.40	—	0.79	—	2.27
560—1100	—	—	0.32	—	0.03	—	0.02	—

temperatures. The amount of water that escapes between 200 and 400 degrees C. is presumably a fairly important building element of the desmite structure, as its removal entails a change in structure. In the opinion of the author, this water either co-ordinates the cations or (with regard to the loss of regenerating ability at 350 degrees C.) plays a role in holding together the layers of the structure.

From the practical point of view, desmite-type minerals may be used up to 250 degrees C. as adsorbing media. Their regeneration is optimum up to 150 degrees.

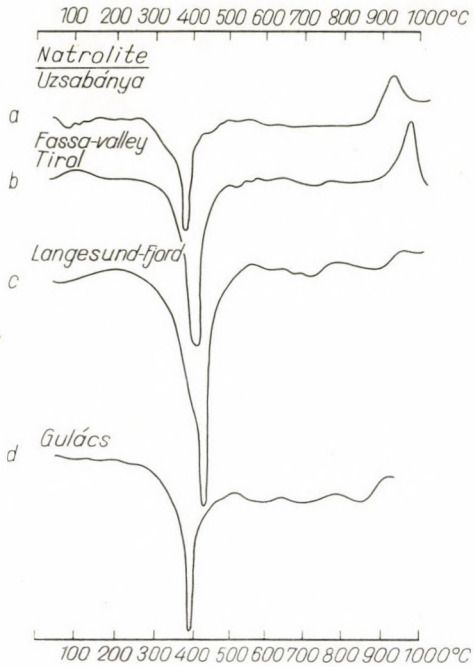

Fig. 9. DTA graphs of natrolites. *a)* Uzsabánya, *b)* Fassa Valley (Tirol), *c)* Langesund-Fjord (Norway), *d)* Gulács

The DTA graphs of ***natrolite*** exhibit, in accord with data found in literature [1, 9, 11, 14, 16, 25, 28], a big sharp endothermic peak between 350 and 450 degrees C. and smaller ones between 450 and 500, 700 and 800, and 800 and 900 degrees, respectively. At the end of the graph between 900 and 1000 degrees there is an exothermic peak that apparently was not noticed by the previous workers. The big peak is indicative of the escape of water [25], the next one of the transformation into metanatrolite, while the exothermic peak reveals a structural rearrangement of a different kind (Fig. 9).

According to MILLIGAN and WEISER [23] the substance turns into a monohydrate between 160 and 180 degrees C. At 250 degrees it loses all its water. HEY [9] states that there is still some water in natrolite between 290 and 300 degrees C., full dehydration occurring only between 460 and 600 degrees.

X-ray diffractograms have been recorded of the Gulács natrolite in the original state, after heating to 500, 680 and 1000 degrees, and of the Fassa

Valley sample also in the original state and after heating to 500, 560 and 1000 degrees C. In spite of careful picking, all our natrolite samples turned out to be contaminated with analcite, whose abundance was revealed by the diffractograms to be about 4 per cent. Analcite manifested itself with undiminished line intensities up to 680 degrees centigrade. After heating at 500 degrees all the d/hkl values of natrolite remained unchanged, only the line intensities showed some decrease. Above 560 degrees the sample was found to consist of alpha carnegieite and nepheline. At 680 degrees C. the substance became roentgenographically amorphous, showing but one or two of the highest-intensity lines of albite and nepheline.

Table 9

Results of chemical analysis of natrolites
(Dr. B. Simó, analyst)

	Uzsabánya	Fassa Valley	Langesund-Fjord	Gulács
	per cent	per cent	per cent	per cent
SiO_2	42.84	47.11	51.93	46.97
TiO_2	—	—	—	—
Al_2O_3	27.70	26.32	23.28	27.45
Total iron	0.13	—	—	—
MnO	0.14	0.01	0.02	—
MgO	—	—	—	—
CaO	3.50	0.66	1.65	0.97
Na_2O	12.24	15.25	13.11	14.18
K_2O	0.24	0.05	0.01	0.48
Total water	12.92	9.85	9.00	10.38
P_2O_5	—	—	— (0.008)	—
CO_2	—	0.80	1.15	—
	99.71	100.05	100.15	100.43

Starting from the ideal formula, the lattice change may be interpreted also stoechiometrically:

$$\underset{\text{natrolite}}{Na_2(Al_2Si_3O_{10})\cdot 2\,H_2O} \xrightarrow{\text{about 480 deg.}} \underset{\text{metanatrolite}}{Na_2(Al_2Si_3O_{10})} + 2\,H_2O$$

$$\xrightarrow{\text{at 560 deg.}} \underset{\substack{\text{alpha carnegie-}\\ \text{ite}}}{2\,NaAlSiO_4} + \underset{\text{nepheline}}{NaAlSiO_4} + SiO_2 \xrightarrow{\text{at 680 deg.}} \rightarrow 2\,\underset{\text{nepheline}}{NaAlSiO_4}$$

Table 10

Trace elements in chabasite, desmite
(Prepared by

	Fe	Sr	V	Cr	K	Ca	Ti	Ni	Co	Ag
Chabasite										
Strzegom	±	++	0	0	+	u	?	?	0	tr
Szob	tr	+	0	?	?	±±	(tr)	0	0	0
Dunabogdány	tr	+	0	0	(tr)	±±	?	0	0	?
Desmite										
Nadap	tr	(tr)	0	0	(tr)	±±	?	0	0	0
Iceland		?	0	0	0	++	((tr))	0	0	0
Dunabogdány		tr	0	0	(tr)	±±	(tr)	0	„—"	0
Strzegom		tr	0	?	(+)	u	?	0	?	0
Natrolite										
Fassa Valley		?	0	0	((tr))	+	((tr))	0	0	0
Gulács		?	0	?	(tr)	±	((tr))	0	0	0

As the diffractograms have revealed no crystalline modification of SiO_2, and the author supposes that compound to be present in a roentgenographically amorphous state.

The chemical composition of the natrolites studied is shown in the Table 9.

As calculated for a basis of 10 O_2 and free of water, the chemical analysis gives the following formulae for our natrolite samples:

Uzsabánya $Na_{0.818}K_{0.022}Ca_{0.259}Mn_{0.007}Al_{2.256}Fe_{0.007}Si_{2.959}O_{10}$
Gulács $Na_{1.746}K_{0.038}Ca_{0.065}Al_{2.055}Si_{2.980}O_{10}$
Fassa Valley $Na_{1.902}K_{0.003}Al_{1.995}Si_{3.028}O_{10}$
Langesund-Fjord $Na_{1.618}Al_{1.741}Si_{3.290}O_{10}$

Taking into consideration also the water content, we have in the same order as above:

$Na_{0.756}K_{0.020}Mn_{0.006}Ca_{0.240}\ Al_{2.086}Fe_{0.006}Si_{2.736}O_{10} \cdot 2.753\ H_2O$ Uzsabánya
$Na_{1.777}K_{0.039}Ca_{0.067}\ Al_{2.020}Si_{2.980}O_{10} \cdot 2.161\ H_2O$ Gulács
$Na_{1.884}K_{0.003}\ Al_{1.976}Si_{2.999}O_{10} \cdot 2.092\ H_2O$ Fassa Valley
$Na_{1.616}\ Al_{1.742}Si_{3.295}O_{10} \cdot 1.985\ H_2O$ Langesund-Fjord

The Hungarian zeolites contain more water and less silica than the others. Both these deviations are considerably more pronounced in the case

and natrolite samples studied
DR. IMRE KUBOVICS

Zn	Cu	Na	Mg	Sn	Pb	Mn	Ge	B	As	Be	Ba	Ga
0	tr	±	±±	((tr))	+	(+)	0	?	?	0	+	0
0	tr	(+)	+	0	0	tr	0	?	?	0	((tr))	0
0	tr	(+)	+	0	0	tr	0	0	0	0	((tr))	0
0	(+)	++	±	0	?	(+)	0	?	?	0	?	0
0	?	((tr))	(tr)	0	0	0	0	0	0	0	((tr))	0
0	(+)	+	+	0	(tr)	(±)	0	0	?	0	?	((tr))
0	(+)	±±	±	0	0	+	0	?	?	(tr)	?	(tr)
0	tr	±±	(+)	0	0	(tr)	0	0	0	0	((tr))	(tr)
0	tr	±±	(+)	0	0	tr	0	((tr))	0	0	(tr)	(+)

of the Uzsabánya sample. Also, the abundance of Ca is substantially higher in the Uzsa zeolite. With reference to the latest results of chemical analysis of the country rock [3] as well as to earlier data concerning its chemical composition and mineralogical constitution [19] the author believes that the basalts of Láz Hill (in which is situated the Uzsabánya quarry), richer in water to begin with than those of the Gulács, underwent secondary influences which, according to BOGNÁR [3] "resulted in the zeolitization of the matrix on the one hand and in the formation of zeolites in the cavities on the other". It was presumably these processes that mobilized the more readily dissolved Ca^{++} ion and furthered the substitution with calcium of the exchangeable cation of natrolite. If the origin of the zeolites out of clay minerals is also taken into consideration [36], the degree of substitution of Si by Al, higher in the Uzsabánya natrolite than anywhere else, also becomes understandable. This is presumably why the mineral is constituted of so many elements and why it is so rich in water.

As to the distribution of trace elements, the Gulács sample does not differ substantially from those from abroad (Table 10).

The infrared spectra of the natrolites studied bear well-defined characteristic peaks (Fig. 10). The peak of the first narrow band is at 3540 cm^{-1}, and that of the next band is at 3300 cm^{-1}. The peak expected at 1640 cm^{-1} is hardly recognizable. The first two peaks indicate the presence of water bound in a crystal-water-like manner; the last, weak one presumably suggests the water content of analcite. A band at 990 cm^{-1} recalls the absorption spectrum of the inosilicate group. The absorption at about 500 cm^{-1} is slightly modified owing

to the substitution of some of the elements by others. The infrared spectra obtained after heating at 300 to 350 degrees C. are completely identical with the aforementioned ones, which is in contradiction to MILLIGAN's and WEISER's hypothesis that natrolite turns into a monohydrate at about 170 degrees and into the dehydrated variety at 250 degrees C. The intensification of the

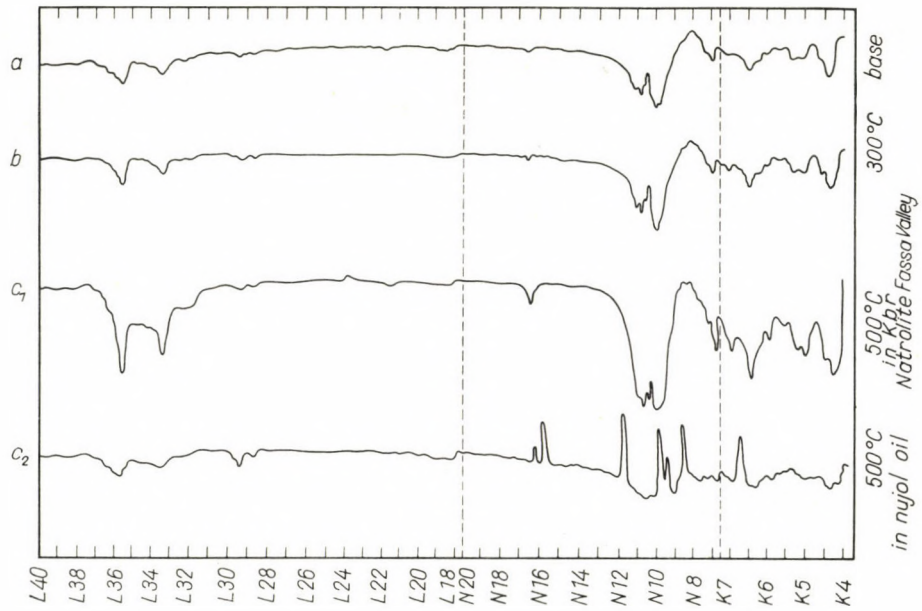

Fig. 10. Infrared spectrograms of natrolite from Fassa Valley. *a)* natural state, *b)* after heating at 300 degrees C., c_1*)* after heating at 500 degrees C. pressed in a KBr pill, c_2 after heating at 500 degrees C. in nujole oil

bands due to the Si—O—Si and Si—O—Al[4] bonds is indicative of a stabilization of the lattice at this temperature. After heating to 500 degrees C. the intensity of the bands due to the oscillation of the OH^- radicals is diminished but stays fairly strong, the silicate bonds are weakened and shifted towards the 1200 cm^{-1} range. After heating at 560 degrees C. a very weak band covering the interval between 3200 and 3600 cm^{-1} indicates practically insignificant oscillation of OH^-, whereas the band between 830 and 1000 cm^{-1} suggests the development of an Si—O—Al[6] type bond. The study of the infrared spectra poses the problem as to whether the water existing in the lattice at these elevated temperatures is still to be classed as crystal water when the X-ray diagrams already indicate a change in lattice structure.

The dehydration graphs of the natrolites studied have been constructed on the basis of the values listed below (Tabl. 11).

Table 11

Weight loss on heating in per cent

Temperature degrees C.	Uzsabánya	Fassa Valley	Langesund-Fjord	Gulács	PENG's data
150	3.65	0.43	0.55	1.43	147 deg. 0.30 262 deg. 2.70
270	12.06	1.95	6.72	10.00	300 deg. 8.40 325 deg. 9.45
430	12.90	9.11	8.42	10.10	400 deg. 4.55 500 deg. 9.07
460	12.90	9.25	8.72	10.10	570 deg. 9.36 655 deg. 9.62
530	13.50	9.25	9.03	10.41	865 deg. 9.92

The dehydration graphs of the Hungarian natrolites slightly deviate from those of the rest. The Hungarian samples lose most of their water content up to 300 degrees C. On the other hand, the Fassa Valley natrolite loses its water above 400 degrees, whereas the Norwegian one loses some of it below 300, the rest above 400 degrees C.

Weight losses on heating in a current of air (Fig. 11 b) are listed below (Tabl. 12).

The water losses of the two samples from Hungary exhibit a fair degree of parallelism, with values slightly higher than those of the natrolites from abroad (Fig. 11 c_1, c_2). The Hungarian samples are seen to lose almost all of their water content up to 270 degrees, those from abroad up to 360 degrees C. The water loss due to heating above those temperatures is quite insignificant.

Table 12

Weight loss as determined by the devolatilization method, in per cent, after heating for two hours

Temperature degrees C.	Uzsabánya	Fassa Valley	Langesund-Fjord	Gulács
160	1.39	0.75	1.19	1.58
160 to 360	8.60	8.66	7.40	8.25
360 to 430	0.70	0.13	0.26	0.81
430 to 470	0.50	0.13	0.11	0.63
470 to 565	0.29	0.16	0.11	0.22
Total	11.48	9.83	9.07	11.49

Table 13

Temperature intervals degrees C.	Uzsabánya		Gulács		Fassa Valley		Langesund-Fjord	
	dehyd.	devol.	dehyd.	devol.	dehyd.	devol.	dehyd.	devol.
Up to 160	—	1.39	—	1.58	—	0.75	—	1.19
150—270	8.50	—	8.57	—	1.52	—	6.17	—
160—360	—	8.60	—	8.25	—	8.66	—	7.40
270—430	0.84	—	0.10	—	7.16	—	1.70	—
360—430	—	0.70	—	0.81	—	0.13	—	0.26
430—460	—	—	—	—	0.14	—	0.30	—
430—470	—	0.50	—	0.63	—	0.13	—	0.11
460—530	0.60	—	0.31	—	—	—	0.31	—
470—565	—	0.29	—	0.22	—	0.16	—	0.11

Temperature intervals degrees C	Peng's	Rozhkova's
	dehydration data	
Up to 147	0.30	—
150 to 260	2.40	—
260 to 300	5.70	—
0 to 300	—	10.09
300 to 400	1.15	1.3
500 to 570	0.29	—

The water loss data obtained by the diverse methods is listed above (Tabl. 13).

The variation of the regenerating ability of natrolites is rather characteristic (Fig. 12). Up to 250 degrees C. weight loss is not more than 2 per cent: of course, no recovery is to be expected under such circumstances. At 300 degrees C. every sample studied exhibited the highest weight loss and fullest recovery. It happened exclusively at this temperature that the samples systematically took in more water than they had lost (a minimum of one and a maximum of four per cent per day). After having lost its water occurring in crystal-water-type bond, natrolite is capable of taking in up to 40 per cent more water than it contained originally. The phenomenon is presumably due to the fact that at this temperature the lattice becomes metastable, with an increase in lattice distances (Fedosseev) entailing a higher water intake capacity. At higher temperatures the lattice stabilizes, water loss is insignificant as compared with that observed in the lower temperature ranges, but the ability to recover still exists. Above 400 degrees C. the definite stabilization of the lattice is indicated by the loss of regenerating ability. Slight increases in weight are

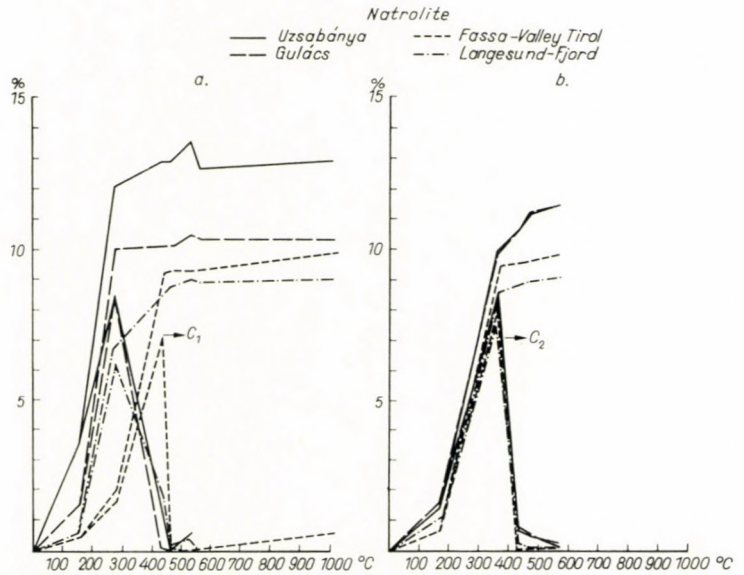

Fig. 11. Dehydration (*a*), devolatilization (*b*) and weight loss graphs of na trolites (c_1 — weight loss on dehydration, c_2 — on devolatilization)

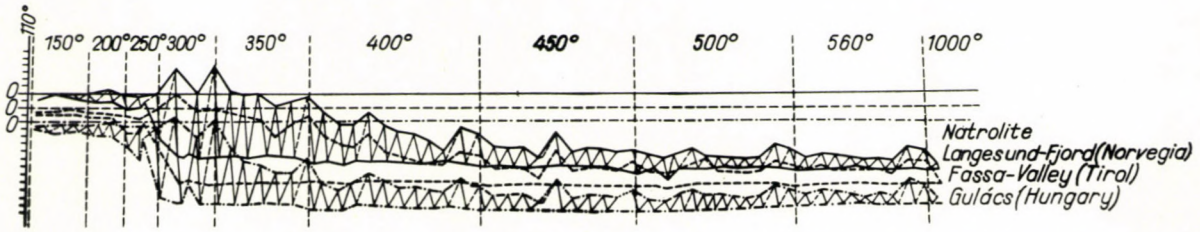

Fig. 12. Regeneration graphs of natrolites

to be attributed to adsorption on the surface. At 450 degrees C. a further slight weight decrease is observed.

The water molecules of natrolite play an important part in linking the chains of the lattice [7]. Bound at a very well-defined energy level, they evacuate within a narrow interval of temperature [25, 28]. However, a review of the above results shows that besides the two moles of water in crystal-water-type bond escaping at the big peak of the DTA graph at 450 degrees C., natrolite contains some more water liberated according to the infra-red spectrograms only above 500 degrees C. This water (perhaps derived from the water cast off at lower temperatures) is presumably bound as OH^- to the aluminium ion in the process of the change of co-ordination of the aluminium brought about by the transition of natrolite to nepheline, a transition entailing the building up of a space lattice.

From the practical point of view, natrolites and natrolite-type zeolites heated to 300 degrees C. are best suited as adsorbents. Heating above that temperature results in rather poor efficiencies.

REFERENCES

1. Berg, L. G. and Rassankaya, J. S.: Dokl. Akad. Nauk SSSR **81,** 518, 1958. — 2. Bidló, G.: Földt. Közl. **86,** 475, 1956.—3. Bognár, L.: Ann. Univ. Sect. Geol. **8,** 3, 1964. — 4. Coblentz, W. W.: Investigation of Infrared Spectra. Parts III and IV. Washington D. C. Carnegie Institution of Washington 1906. — 5. Coombs, D. S.—Ellis, A. J.—Fyfe, W. S.—Taylor, A. M.: Geochim et Cosmochim. Ac. **17,** 53, 1959. — 6. Cseszkó, M.: Földt. Közl. **88,** 315, 1958. — 7. Deer, W. A.—Howie, R. A.—Zussmann, J.: Rock Forming Minerals 4. Longmans, London, 1963. — 8. Halla, F.—Mehl, E. :Zeitschr. f. Krist. **75,** 421, 1930. — 9. Hey, M. H.: Min. Mag. **23,** 243, 1932. — 10. Hey, M. H.—Bannister, F. A.: Min. Mag. **23,** 556, 1934. — 11. Ivanova, V. P.: Termogrammy mineralov. Zap. Vsesoyuz. mineral. ob-va, 2. ser. 90. Izdvo AN. SSSR, M.—L. 1961.—12. Yukhnevich, G. V.: Sravnitelnaya kharakteristika nekotorykh zeolitov metodom infrakrasnoy spektroskopii. "Geokhimiya" No. 10, 1962.—13. Карюкина, В. Н.: Определение содержания воды в минерале с помощью инфракрасных лучей. Сб. «Современные методы минералогического исследования горных пород, руд и минералов.» Госгеолтехиздат, М. 1957. — 14. Koizumi, M.: Min. Journ. **1,** 36, 1953. — 15. Koizumi, M.: Science Reports **7,** 115, 1958. — 16. Kožu, S. and Masadu, M.: Sci. Rep. Tohoku, Imp. Univ. Ser. **3,** III. 32, 1929. — 17. Mauritz, B.: Neues Jahrb. Min. Geol. Pal. **64,** 477, 1931. — 18. Mauritz, B.: Min. Petr. Mitt. **48,** 373, 1936. — 19. Mauritz, B.: Földt. Közl. **78,** 134, 1948. — 20. Matozsi, Frank, Krüger: Zeitsch. f. Physik **99,** 1, 1936. — 21. Meier, N. M.: Zeitsch. f. Kristallographie **113,** 430, 1960. — 22. Milkey, R. G.: Am. Min. **45,** 990, 1960. — 23. Milligan, W. O. and Weiser, H. B.: Journ. Phys. Chem. **1,** 1029, 1937. — 24. Moenke, H.: Spektralanalyse von Mineralien und Gesteine. Ak. Verlag. Geest und Portig K. G. Leipzig, 1962. — 25. Peng, G. J.: Am. Min. **40,** 834, 1955. — 26. Pécsi-Donáth, É.: Acta Geol. **VI,** 429, 1962. — 27. Reichert, R.—Erdélyi, J.: Min. Petr. Mitt. **46,** 237, 1935. — 28. Roskova, E. V.—Jeresova, K. S.—Andrusenko, N. U.: Mineralnoe syre, Vyp. **6,** 1, 1962. — 29. Schafarzik, F.: Földt. Közl. **14,** 299, 1884. — 30. Scherf, E.: Zentralbl. Min. — 31. Scholz, H.—Dietzel, G.: Naturwiss. **42,** 342, 1955. — 32. Scholz, H.: Fortschr. Min. **38,** 122, 1960. — 33. Serratosa, J. M.: Amer. Min. **45,** 110, 1960. — 34. Smith, J. N.: Acta Cryst. **15,** 835, 1962. — 35. Smith, J. W.—Rinaldi, F.—Dent—Glaser, L. S.: Acta Cryst. **16,** 45, 1963. — 36. Szádeczky-Kardoss, E.—Erdélyi, J.: Földt. Közl. **88,** 315, 1958. — 37. Szádeczky-Kardoss, E.: Földt. Közl. **88,** 171, 1958. — 38. Szádeczky-Kardoss, E.: Zeitschr. der Geol. Gesell. Sonderheft. Freiberg, 1962. — 39. Taylor, W.—Meek, C.—Jackson, W.: Zeitschr. Kryst. **84,** 373, 1933. — 40. Taylor, W. H.: Perc. Roy. Soc. A. **145,** 80, 1934. — 41. Vendl, A.: Földt. Közl. **41,** 195, 1911. — 42. Weigl, O.: Naturwiss. 1, 1919. — 43. Whilan, J. A.: Bull. Geol. Soc. Amer. **71,** 2001, 1960. (Abstract.) — 44. Wyart, J.: Bull. Soc. Franc. Min. **56,** 81, 1933.

СПЕЦИАЛЬНЫЕ ОСОБЕННОСТИ ЦЕОЛИТОВ ВЕНГРИИ

Э. ПЕЧИ-ДОНАТ

Р е з ю м е

При разностороннем, сравнительном изучении цеолитов особое внимание было уделено, из числа зеолитов встречающихся в некоторых андезитах и базальтах Венгрии, *шабазитам* из месторождений андезитов в сс. Дунабогдань и Соб, *десмину* из месторождения Дунабогдань, а также *натролиту*, встречающемуся в базальтах месторождений Гулач и Ужабанья, причем их свойства были сопоставлены с теми же самыми видами цеолитов других вмещающих пород из-за границы.

«Цеолитные воды» венгерских шабазитов — аналогично цеолитам других местонахождений — относятся ко двум разновидностям. Слабее связанные воды, удаляющиеся до температуры 220° С и во вторых более прочно связанные «адсорбционные воды», удаляющиеся при более высокой температуре. В строении дунабогданьского шабазита вода играет более значительную роль, чем в шабазитах остальных местонахождений, имея в виду их генезис.

Структура шабазитов при удалении воды не изменяется до 560° С. Однако, при нагревании до 1000° С она изменяется: дунабогданьский шабазит превращается в анортит, собский — в анортит-барбьерит, а шабазит из месторождения Стржегом — в плагиоклаз-полевой шпат с составом, промежуточными между анортитом и битовнитом + ортоклаз (содержание K_2O—1,67%!).

«Цеолитная вода» десмина является существенной частью кристаллической структуры, и в сцепке пластинчатой структуре вероятно играет важную роль

При температуре 250° С они превращаются в гейландит-вайрикит или в клиноптилолит, соответственно, а при 400° С можно отождествить их опять с десмином (отличающимся редкостью линий). При температуре 1000° С они превращаются в анортит.

«Цеолитные воды» натролитов представляют собой отчасти «воды, связанные вроде кристаллизационной воды», отчасти «адсорбционные воды», причем они играют важную роль в сцеплении звеньев цепей. Более сильно связанная вода сохранится в небольшом количестве даже при нагревании до температуры 500° С.

В процессе своего превращения рассматриваемые образования при температуре свыше 560° С превращаются в α—карнегиеит + нефелин, при 680° С — в нефелин + альбит, а при 1000° С — в нефелин.

В соответствии с петрохимическими условиями породы, натролиты венгерских базальтов характеризуются с большим содержанием Ca^{++} и воды, а также более сильным замещением Al—Si.

VERTICAL ZONING OF CLAY MINERALS ACCOMPANYING A HYDROTHERMAL MINERALIZATION

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Mining operations and a deep research boring in the gold and silver region (Telkibánya) of the Tokaj Mountains a member of the Intra-Carpathian Tertiary volcanic wreath, have permitted to trace the clay mineralization accompanying the ore veins and the ore mineralization over a vertical extent of 1400 to 1500 metres.

Detailed geological, petrographic and mineralogical studies have resulted in the distinction of three clay mineral facies.

1. At the higher levels, the veins carrying the precious metals are frequently accompanied by considerable kaolinization. Kaolinite is also a frequent clay mineral in the ochre and limonitic veins in the so-called zone of oxidation. Its depth range is limited to less than 100 metres below the surface. The concentration of the precious metals in the kaolinitic facies is very slight.

2. Montmorillonite may be considerably enriched besides kaolinite, near the surface, but it is down to 200 and even 300 metres depth that it is the really predominant clay mineral. In tectonic fissures, joints and veins it frequently occurs at depths reaching 500 metres. Its formation, akin to that of kaolinite, is due to a considerable extent to the influence of descending solutions that originated at the surface. In the montmorillonitic filling of the veins, enrichment of the precious metals is the highest. These were the levels that were worked in the early phases of mining at Telkibánya (XIV., XVI., XVIII. century).

3. Below the horizon of montmorillonite, there is a widespread horizon of clinochlore-bearing andesitogenic propylite, which over a depth range of 1500 metres gradually changes into the higher-temperature epidote facies of propylite. It is this propylite that accompanies the primary sulfidic ores.

On the border of the montmorillonite zone and the propylite zone there occur, as proved by X-ray diffractometry and DTA methods, substantial amounts of montmorillonite, chlorite and clay minerals of mixed-layer types.

In the course of the study of ore deposits and mineralized zones, attention is usually focussed on the ore while relatively little thought is given to the important relations that exist between the ore filling of the veins on the one hand, and the decomposition of the country rock accompanying the ore mineralization, on the other. Nor is the volume ratio of unaltered orthomagmatic and altered hypo- and metamagmatic rocks taken into proper consideration. Of hypo- and metamagmatic rocks (SZÁDECZKY-KARDOSS's system of transvaporized rocks, 1956) it is only the hydro rocks accompanying ore mineralization, that is, the clay mineralization accompanying hydrothermal ores, that were examined in a more or less proper perspective by such workers as LINDGREEN (1933), SUDO (1962, 1963), CHUKHROV (1962), MILLOT (1964). This interest in clay minerals is to some extent due to the growing popu-

larity of clay mineral studies all over the world, because hydrothermal mineralization is the site of various special types of clay minerals and of mixed-layered structures.

Observations made by the above-mentioned authors were mostly restricted to establish the zoning of clay minerals as governed by the chemical composition and mineral products of the ore-bearing solutions in and near the ore-bearing veins. A few authors — (CHUKHROV 1962) — pointed out the importance of descending solutions in the formation of clay minerals besides that of the ascending ore-bearing solutions.

According to findings by the present author, to be detailed below, clay mineralization in the strict sense is rather restricted in vertical extent in the hydrothermal ore deposits of volcanic mountains, as compared to other processes of rock decomposition. It is to be considered a large-scale regional process only in case propylitization, characterized by the presence of chlorite, is also regarded as a clay mineralization.

The Telkibánya area of precious metal mineralization in the Tokaj Mountains, Northeast Hungary, a member of the Tertiary volcanic wreath of the Carpathian Basin, is excellently suited to differentiate the manifold factors contributing to clay mineralization. It is very seldom that one encounters a vertical section of such a considerable extent as offered by the Telkibánya area. The highest peak, Kánya Hill, elevated 600 m a. s. l., as well as the various mines and a drill hole sunk to a depth of 1240 metres for the purpose of prospecting — all these taken together disclose the clay mineralization over a vertical extent of 1400—1500 meters.

This extraordinary vertical exposure enables to distinguish the ascendant (hypogene, hydrothermal) and descendant (supergene) solutions and also makes it possible to establish the vertical sequence of the clay mineral zones accompanying ore mineralization.

The occurrence of clay minerals at well-defined levels in the northern part of the Tokaj Mountains was already pointed out by SCHERF (1952) who stated that clay mineralization is observed in numerous instances in the Kéked-Telkibánya region and in wide belts of altered rock further south. Clay mineralization has a well-defined optimum level and clayey alteration is practically absent at elevations higher than 500 metres above sea level.

The present author has found that clay mineralization in the strict sense of the word is most intense near the outcrop of the hydrothermal veins and it gradually loses intensity downwards. This is valid both for the eastern and western side of the area, that is, for both the Gyepü Hill and Kánya Hill mineralizations (Fig. 1) respectively.

First the western, Gyepü Hill mineralization shall be considered. In the so-called kaolin adits of Gyepü Hill, particularly in Kaolin Adit No. 1 (74 metres above sea level), János Vein is accompanied by several metres thick

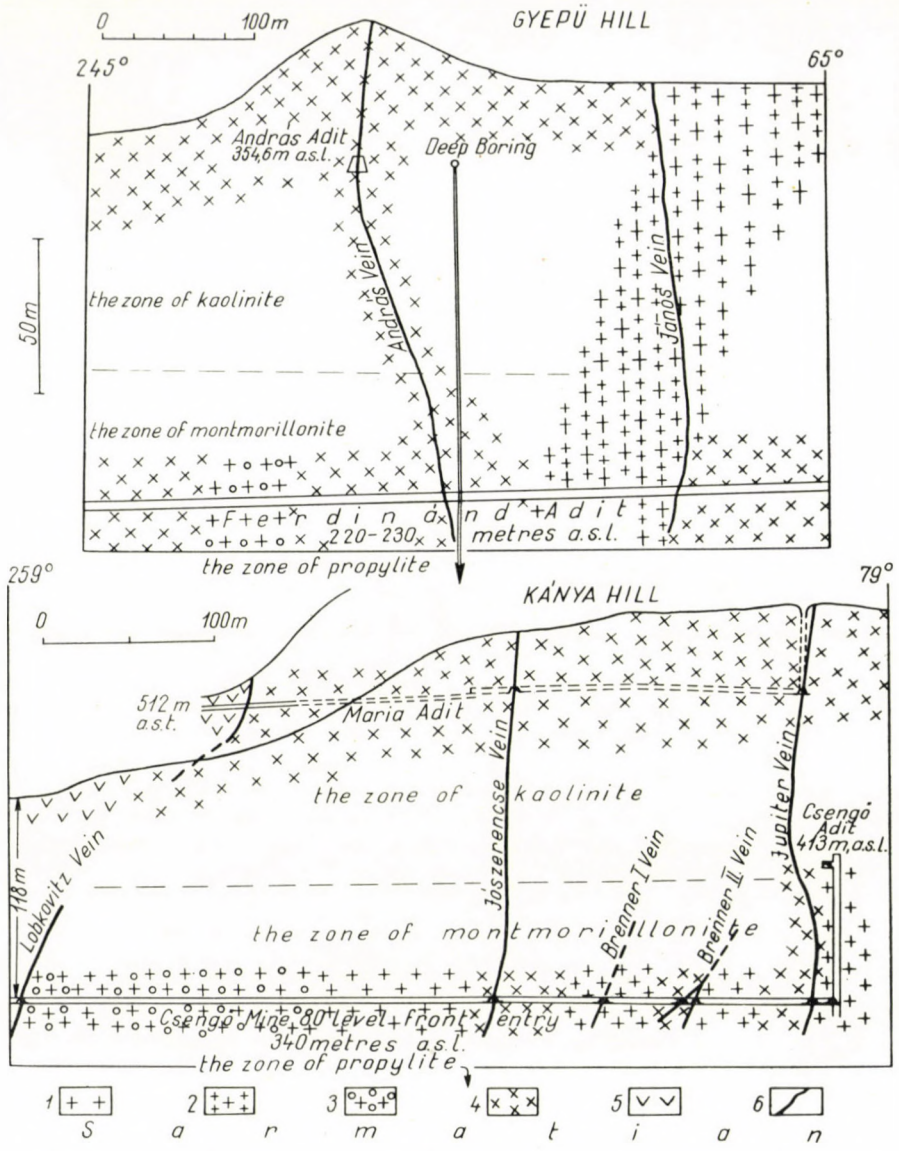

Fig. 1. Geological section of the Gyepü Hill and Kánya Hill, Telkibánya area of precious metal mineralization in the Tokaj-Mountains (Hungary)

1. pyroxene — orto- and hydro-andesite, 2. amphibolic pyroxene-andesite, 3. andesitogenic propylite (chlorandesite), 4. potash trachyte and potash hydrotrachyte, 5. rhyolite, 6. ore vein

industrial-grade exploitable kaolin (Fig. 2). From Kaolin Adit No. 2, ten metres above, kaolin was mined more than a century ago. Examinations by diverse techniques as well as the DTA graph indicate the preponderant clay mineral to be kaolinite accompanied by some illite (Fig. 3). Kaolin was formed out of pyro-

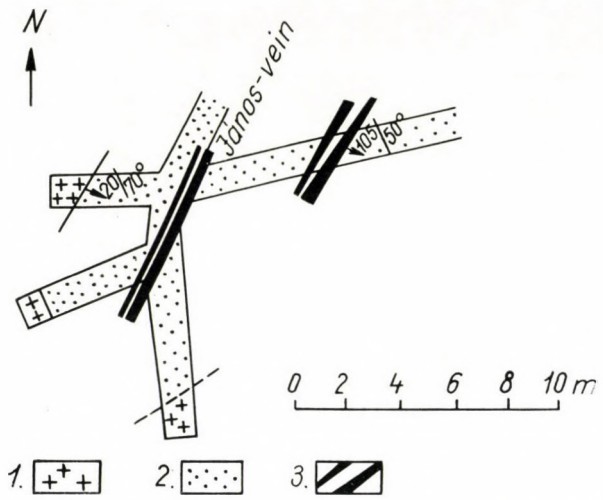

Fig. 2. The János Vein accompanying andesitogenic kaolinization in Kaolin Adit No. 1 (375 metres above sea level)
1. hydroandesite, 2. andesitogenic kaolin, 3. pyrite stringer

xene andesite through a hydroandesitic intermediary stage. According to LIFFA (1955), András Vein at a level identical with that of Kaolin Adit No. 1 is likewise accompanied by 40 metres of kaolin formed out of pyroxene andesite.

Proceeding, however, downward along the Gyepü Hill veins, János and András, the amount of kaolin gradually decreases. In the longest exposure of Gyepü Hill, in Ferdinand Adit (220 to 230 metres above the sea level) kaolin is quite subordinate. Among the secondary minerals accompanying András

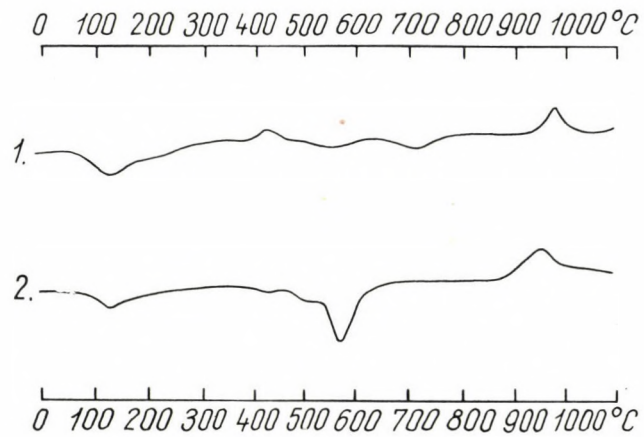

Fig. 3. DTA graphs of the János Vein accompanying kaolin (from Kaolin Adit No. 1.)
1. pyroxene-hydroandesite, 2. andesitogenic kaolin

Vein (diverse hydrated sulfates, phosphates, iron oxides), indicating the penetration of the zone of oxidation down to the level of Ferdinand Adit, there is still some kaolinite, but in the vein itself and in the clayey filling of the small internal shaft sunk from Ferdinand Adit, montmorillonite makes an appearance (Fig. 4). However, it has been impossible to prove the presence of montmorillonite except in the washing residue of the vein fill, because the clay minerals are generally hidden by the ore minerals and also by the youngest set of carbonates (siderite, dolomite, magnesite, ankerite) present in the vein.

Below the level of the Ferdinánd adit, however, even montmorillonite disappears. Neither could any montmorillonite be ascertained in a 1240 metres

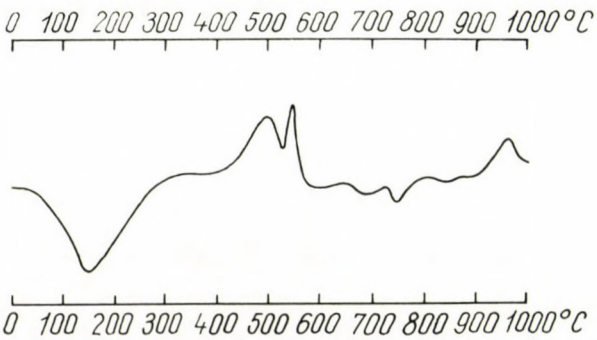

Fig. 4. DTA graph of the clayey part of the András Vein, Ferdinand Adit (220 to 230 metres above sea level)

deep boring sunk near András Adit except for the vein fillings of the upper levels to some 400 metres depth along the boring. At the lower levels no kaolinite or montmorillonite is found at all in connection with the ore shoots, nor in the fissures or joints of the country rock. Below a depth of 400 metres counted from the surface (equalling 50 metres below sea level) the predominant clay mineral is chlorite, more exactly clinochlore which is accompanied by some vermiculite (Fig. 5).

In the depth interval of 400 to 500 metres counted from the surface, both microscopic studies and DT and X-ray diffractometry analysis (Fig. 5, 6, 7) have proved the presence of a clay mineral of an interstratified montmorillonite (vermiculite)-chlorite structure. As revealed by the figures the results obtained by the above-mentioned procedures agree fairly well with BRADLEY's (1955, 1956) findings concerning magnesium hydrosilicates of regular interstratified structure.

The mixed-structure clay minerals of epithermal ore deposits have lately been dealt with by SUDO et al. (1962). According to their findings, minerals of regular interstratified montmorillonite-chlorite structure most often occur at

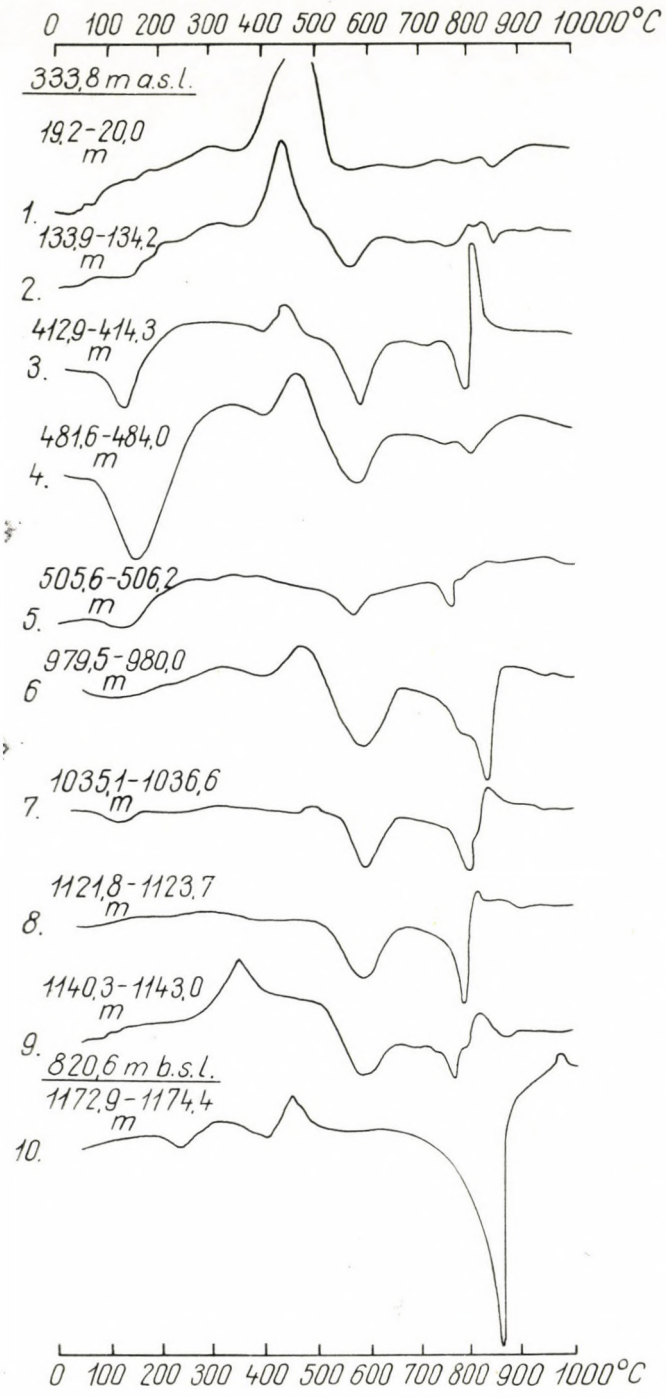

Fig. 5. DTA graphs of hydrolytites and hydroandesites from different depth of the 1240 metres deep boring in the Baglyas Valley (353 metres above sea level), sunk near András Adit.

1. pyrite stringer in potash trachyte, 2. clayey stringer in potash trachyte, 3. clayey vein with interstratified vermiculite-chlorite clay minerals, 4. clayey vein, with interstratified montmorillonite-chlorite clay minerals, 5. hydro-chloroandesite, 6. hydropropylite, 7. calcite stringer in propylite, 8. hydropropylite, 9. hydropropylite, 10. calcite stringer in propylite

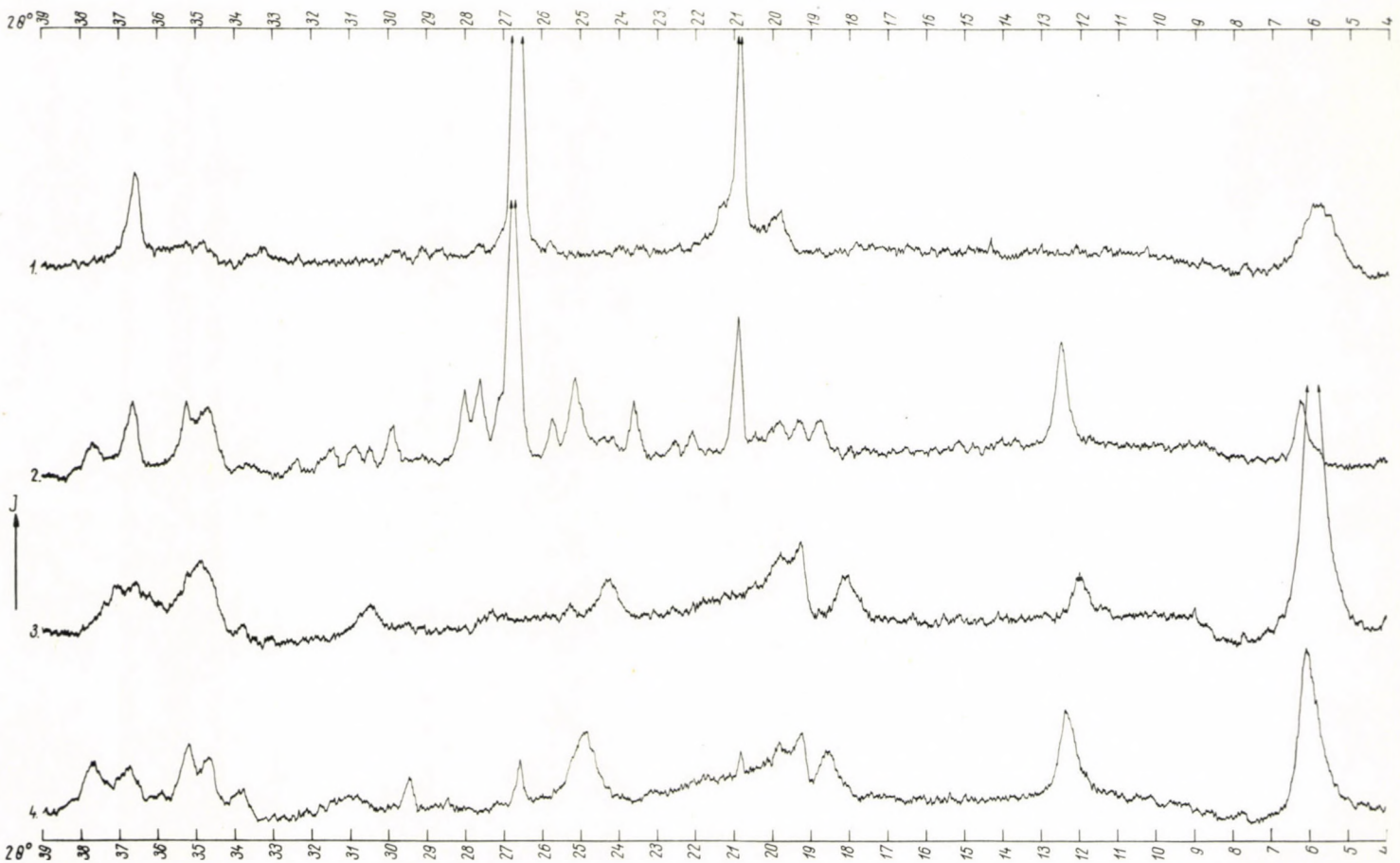

Fig. 6. X-ray diffraction graphs of clayey veins from different depth of precious metal mineralization in the Telkibánya area

1. vein-clay with montmorillonite from Jószerencsét Vein, Mária Adit (512 metres above sea level), 2. chloroandesite with montmorillonite and chlorite, Csengő Mine (340 metres above sea level), 3. clayey vein with interstratified vermiculite-chlorite clay minerals, 413 m from deep boring (59 metres below sea level), 4. clayey vein with interstratified montmorillonite-chlorite clay minerals, 482 m from deep boring (128 metres below sea level)

the margin of galena and sphalerite ore bodies and also in the band of transition between the montmorillonite and chlorite-illite zones. The transitional clay mineral zones of epithermal ore deposits are apparently characterized, at large, by regular mixed-layered minerals. These may be of widely varied origin. The

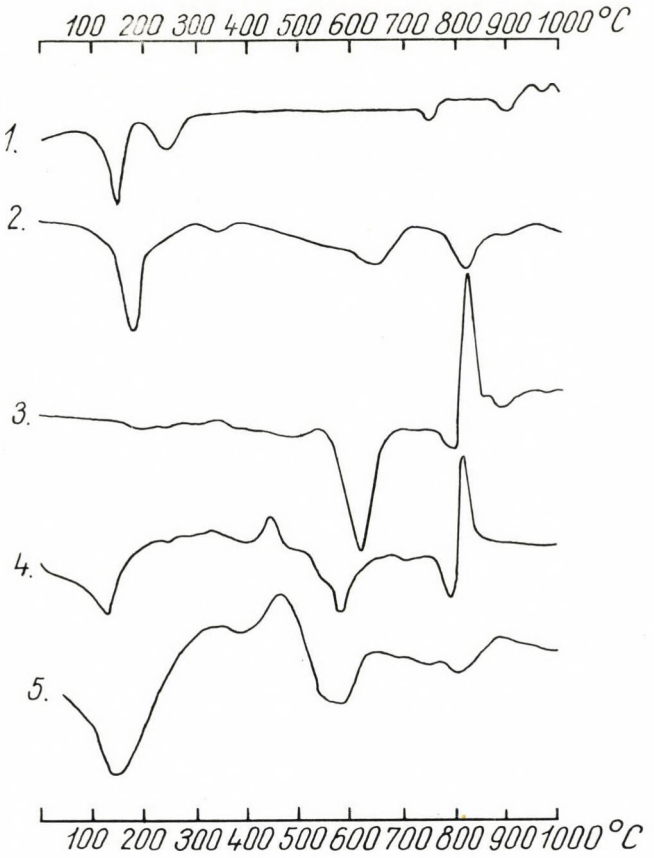

Fig. 7. DTA graphs of vermiculite, montmorillonite, chlorite and regularly mixed-layered clay minerals

1. typical vermiculite, 2. typical montmorillonite, 3. typical chlorite, 4. clayey vein with interstratified vermiculite-chlorite clay mineral, 413 m from deep boring (59 metres below sea level), 5. clayey vein with interstrafied montmorillonite-chlorite clay mineral, from a depth of 482 m in a deep boring (128 metres below sea level)

nature of the interstratified lattice plane, the formation of regular or irregular mixed lattices is governed by external factors. If in an environment previously favouring the formation of a mineral "A" the conditions change so as to promote the formation of a mineral "B", there form minerals that, in the opinion of SUDO (1962), represent a gradual transition from A to B. In the region under discussion, over a depth of from 400 to 500 metres from the surface, this prin-

ciple is realized as follows: chlorite → deformed chlorite containing montmorillonitic (vermiculitic) complexes→chlorite-montmorillonite (vermiculite) mixed-layered structure → montmorillonite (vermiculite) containing chloritic complexes of layers → montmorillonite (vermiculite).

At depths greater than 500 metres below the surface, chlorite (clinochlore) becomes dominant.

All the above minerals are as a rule accompanied by pyrite, calcite and epidote. This clay mineral assemblage, stabilized, as it were, at the higher temperature range of the propylite facies, remains unchanged — as proved also by DTA graphs (Fig. 5) — all the way down to 1240 metres.

The clay mineral filling of the Kánya Hill veins in the eastern half of the area exhibits a substantially similar vertical zoning (Fig. 1). In Mária Adit, the disclosures of highest elevation (511 metres above the sea) of the quartzose parts of the principal veins (Lobkovitz, Józserencsét) of Kánya Hill exhibit, besides some largely non-crystalline iron hydroxide hardly revealed by the DTA graph, a minor amount of kaolinitic clay mineral. Furthermore, the considerable extent of kaolinization at this upper level is indicated by the fact that on the eastern flank of Kánya Hill, around Hollóháza, several tunnels disclosed kaolin of industrially exploitable grade. (The DTA graphs here presented have also been taken on the washed colloidal fraction of the samples, in order to obtain a clearer idea of the clay mineral.) In the veins of Mária Adit, however, montmorillonite also crops up besides kaolinite, partly as a result of a supergene process of mineralisation (Fig. 8).

At the 80-metre level of Csengő Mine, nearly 200 metres below the level of Mária Adit, the clay mineral assemblage is different. In the vein filling and in the country rock directly adjacent to the vein, the predominant clay mineral is montmorillonite (Fig. 9). It is, however, nowhere accompanied by kaolinite, in contrast to that found at the higher levels. Indeed, it is chlorite (clinochlore) that crops up, particularly in the vast volumes of propylite between the veins. X-ray diffractometry of propylite has proved the presence of 35 to 40 percent of clinochlore and as little as 5 to 10 per cent of montmorillonite (Fig. 6). Even these data suffice, however, to state in analogy with Gyepü Hill that also on Kánya Hill, though data concerning the deeper levels are lacking, clay mineralization in the narrower sense is presumably substituted deeper down by a clay mineralization in the broader sense, namely, a clinochlore-bearing propylite.

Let us consider the vertical zoning of the clay mineralization outlined above in the light of the evolution of the region. In the zone of the Carpathian volcanic wreath, hydrothermal ore formation had been preceded, as has been pointed out by the present author (Széky-Fux 1964) by a hypogene hydrothermal phase of considerable extent, which caused propylitization over a vertical range of almost 1000 metres. Along the fault lines (veins) directing the advance

of the hydrothermal solutions, potash trachyte and potash metasomatites were formed at the higher levels under higher oxidation potentials. The ore-bearing solutions partly interwoven with and partly subsequent to potash metasomatism resulted in a substantial decomposition of the country rock particularly at the higher levels. Near the surface where leaching was strongest a kaolinitized body of rock of considerable horizontal but insignificant vertical dimensions came to exist.

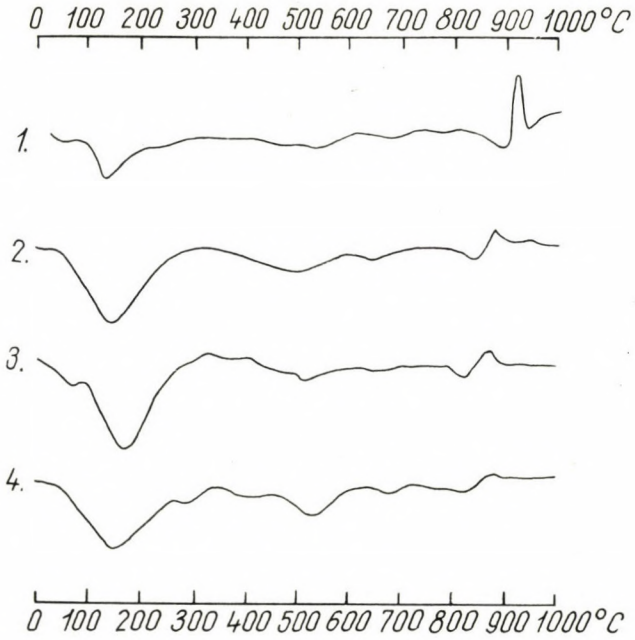

Fig. 8. DTA graphs from ochreous clay stringers of Jószerencsét Vein, Mária Adit (512 metres above sea level), Kánya Hill
1. with kaolinite predominant, 2—4. with montmorillonite predominant

In the further evolution of the clay mineral fillings also the descendant solutions seeping downwards along tectonic lines, fissures and vein-type formations played an important role. These solutions penetrated deep below the so-called zone of oxidation, to a depth of 200 to 300 metres below the outcrops of the veins, producing mostly montmorillonite at the deeper level of the near-surface zone.

In the kaolinitic-pyritic ore veins the enrichment of precious metals is insignificant. On the other hand, at the montmorillonitic levels of these same veins or in other veins of montmorillonitic filling, precious metals occur in the highest abundance. Consequently, *montmorillonite is an excellent adsorbing medium for the precious metals, too.* This is why ancient precious metal mining was bound to the montmorillonitic level.

The primary sulfidic heavy metal association (sphalerite, galena, chalcopyrite) occurring at a deeper level *is accompanied largely by chloritic propylite.* Besides the hypo- and supergene influences the above-outlined zoning of the clay minerals was also governed to some extent by pressure effects in the deeper zones. Pressure tended to displace the stability field towards chlorite-type products. In other words, it was pressure that preserved the chlorite (or propylite) facies at the deeper levels.

Comparison with other *mineralized regions in the Carpathian Basin* reveals a number of analogous cases of tell-tale *kaolinization at the surface, a*

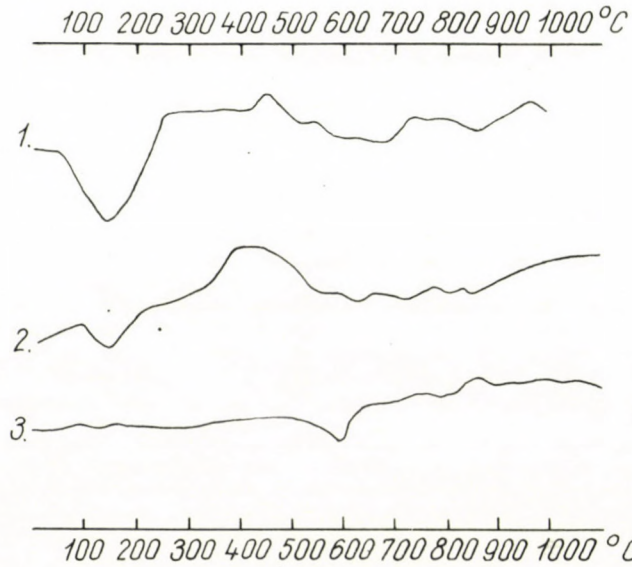

Fig. 9. DTA graphs from clayey parts of the ore veins and chloroandesites, Csengő Mine (340 metres above sea level), Kánya Hill
1. Brenner II. Vein, 2—3. chloroandesites, 80-level front entry

zone of secondary accumulation of precious metals accompanied by montmorillonite below, and heavy metal sulfides accompanied by propylite at the deeper levels. As far as could be ascertained so far, the depth and thickness relations of these zones were invariably connected quite intimately with the local factors of ore formation.

Acknowledgements

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REFERENCES

1. Szádeczky-Kardoss, E.: Int. Geol. Congr. Rep. XXI. Sess. Copenhagen. **XIII**, 260, 1960. — 2. Lindgreen, W.: Mineral Deposits, New York, 1933. — 3. Sudo, T.: Int. Clay Conference **1,** 113, 1963. — 4. Sudo, T.—Hayashi, H.—Shēdoma, S.: Clays and Clay Minerals, **8,** 378, 1962. — 5. Tchoukrov, F. V.: Colloques Internationaux du Centre National de la Recherche Scientifique, Paris, **105,** 159, 1962. — 6. Millot, G.: Géologie des argiles, Paris, 1964. — 7. Scherf, E.: V. sz. Jelentés a Telkibánya környékén végzett bányaföldtani felvétel eredményeiről (Manuscript) 1952. — 8. Liffa, A.: Magyar Állami Földtani Intézet Évkönyve, **XLII,** 211, 1955 — 9. Bradley, W. F.—Weaver, C. E.: The American Mineralogist, **41,** 497, 1956. — 10. Bradley, W. F.: Clays and Clay Minerals. Publication **395,** 94, 1955. — 11. Széky-Fux, V.: Acta Geol. Hung. **VIII,** 97, 1964.

ГЛИНИСТАЯ МИНЕРАЛИЗАЦИЯ, СОПУТСТВУЮЩАЯ ГИДРОТЕРМАЛЬНОМУ ОРУДЕНЕНИЮ

В. СЕКИ-ФУКС

Резюме

На рудоносной (Au—Ag) площади Токайских гор, расположенных в третичной зоне Карпат (Телькибанья), горнорудные работы и структурно опорные скважины позволили проследить рудные жилы или сопутствующую оруденению глинистую минерализацию в пределах глубинного интервала 1400—1500 м.

На основании детальных геологических, петрографических и минералогических исследований автором были выделены три фации глинистых минералов.

1. Жилы, содержащие благородные металлы, на более высоких горизонтах, сопровождаются каолинизацией, которая является широко распространенным глинистым минералом также и охристых-лимонитовых жил в зоне окисления. Глубинное распространение каолинизации ограниченное, чаще всего она не распространяется даже до глубины 100 м от дневной поверхности, причем концентрация благородных металлов в них является минимальной.

2. Наряду с каолинитом, часто уже вблизи поверхности обогащается и монтмориллонит, который является преобладающим минералом до глубины 200—300 м от поверхности. В тектонических линиях, трещинах, трещинных образованиях он часто наблюдается даже на глубине 400—500 м. В его генезисе сыграли — аналогично каолиниту — нисходящие с поверхности (десцендентные) растворы весьма важную роль. В монтмориллонитовых выполнениях жил наблюдается максимальное обогащение благородных металлов. Старая горная разработка руд благородных металлов в месторождении Телькибанья приурочивалась как раз к этим горизонтам.

3. Под монтмориллонитовым горизонтом располагается регионально распространенный клинохлороносный, андезитогенный пропилит, который до глубины 1500 м постепенно переходит в более высокотермальную эпидотную фацию пропилитов. Первичным сульфидным рудообразованиям сопутствует такой пропилит.

На границе между монтмориллонитовой и пропилитовой зонами появляется значительное количество монтмориллонита-хлорита, глинистых минералов смешанного строения, что подтверждается данными изучения проб при помощи рентгеновского дифрактометра и дифференциально-термических анализов.

PÉTROGRAPHIE DU MASSIF SUBVOLCANIQUE DE TOROIAGA (CARPATES ORIENTALES, R. S. ROUMAINE)

Par

A. SZŐKE

L'ACADÉMIE DE LA R. S. ROUMAINE, BUCUREŞTI

Le massif subvolcanique de Toroiaga constitue la partie méridionale des Monts de Maramureş. Il fait partie de la chaîne volcanique tertiaire, situé au flanc interne de l'arc des Carpathes Orientales.

Son périmètre consiste en roches cristallophylliennes (schistes chloriteux et sériciteux, porphyroïdes, quartzites noires, etc.), sur lesquelles reposent les sédiments crétacées, éocènes et oligocènes du bassin de Maramureş.

L'ensemble éruptif de l'andésite à hornblende et à biotite forme un corps subvolcanique, allongé en direction NW—SE, d'un contour irrégulier; entouré par un système de dykes de composition andésitique. Le caractère subvolcanique du massif éruptif est prouvé par les faits suivants: l'absence totale des traces d'un volcanisme superficiel; transition graduelle de la structure des roches du massif éruptif de bas en haut. Elle est dans les parties inférieures macrocristalline (diorites quartziques), en montant elle passe dans des andésites dont le degré de la cristallinité diminue graduellement et se termine en haut, immédiatement au-dessous du toit par des andésites à pâte vitreuse. On peut suivre cette transition dans une distance verticale de 1000 mètres environ sans un changement notable de la composition minéralogique. Il a réussi de démontrer en plusieurs endroits les traces de l'ancien toit du massif éruptif: des roches cristallophylliennes et des brèches de contact.

Les effets pneumatholitiques, accompagnants l'intrusion ont engendré une tourmalinisation au contact de l'andésite et des roches cristallophylliennes. Des phénomènes hydrothermaux ont produits de leur part des filons avec des minéralisations sulfuriques, traversant le subvolcan transversalement. Le long des filons on voit une altération considérable des roches (qui se manifeste en propilitisation, formation de l'épidote, pyritisation, sériciteisation, kaolinitisation, silification, etc.).

Les dykes, éloignés de la partie centrale du massif, s'enfonçants dans les sédiments éocènes et oligocènes nous fournissent quelques vagues ranseignements concernant l'âge du massif andésitique.

Introduction

La présente étude s'occupe du massif subvolcanique de Toroiaga, situé dans la région méridionale des Monts du Maramureş.

La région fait partie des Carpates Orientales, qui, partant de l'Ukraine subcarpatique, se continuent dans la direction SSE, jusqu'à la courbure des Carpates, d'où elles se dirigent vers l'ouest jusque dans la vallée de la Dîmbovitza. Du point de vue géologique, les Carpates Orientales sont constituées par trois zones parallèles allongées dans la direction de la chaîne montagneuse. En partant de l'ouest vers l'est ces zones sont les suivantes:

— Zone cristalline mésozoïque;
— Zone du flysch;

— Zone néogène ou subcarpatique.

Dans le soubassement cristallin on distingue deux séries de roches, dont le premier Groupe I. est constitué de roches plus fortement métamorphisées de cata- et de mésozone, comprenant des micaschistes à granats, des schistes à biotite et à amphibole, des amphibolites, des gneiss à amphibole et à biotite, parfois même des calcaires cristallins. Le Groupe II. est formé de schistes cristallins d'épizone, où prédominent les schistes chloriteux, les phyllites, les phyllites argileux, les quartzites noirs et les calcaires blancs cristallins. Il y a, entre ces deux groupes, des rapports de superposition anormaux, la série cata-mésozonale chevauchant la série épizonale. Mais ces chevauchements n'atteignent pas l'ampleur des nappes de charriages.

Le soubassement cristallin a été recouvert de dépôts mésozoïques, en grande partie détruit par l'érosion; il n'en reste que de petits lambeaux isolés. Les dépôts se sont formés durant trois cycles de sédimentation; Trias-Lias, Dogger-Barrémien et Gault-Sénonien. La sédimentation mésozoïque n'a pas été continuelle, elle a été interrompue de temps en temps par le retrait de la mer, provoqué par l'exondation de la zone de sédimentation.

A l'intérieur du flysch on distingue une zone interne (occidentale) et une zone externe ou marginale. La zone interne, située à l'est de la zone cristalline-mésozoïque, est formée de couches d'âge valanginien-hauterivien, barrémien-aptien, et gault-cénomanien-aptien. La zone externe du flysch, située à l'est de la zone interne, se compose de dépôts sénoniens, paléocènes, éocènes et oligocènes.

La zone la plus externe des Carpates Orientales, la zone néogène ou subcarpatique, est formée presque exclusivement de dépôts d'âge miocène et pliocène. Ce n'est que dans les plis anticlinaux qu'apparaissent parfois des couches plus anciennes. Le Miocène est représenté par le Méditerranéen I. (Aquitainien-Burdigalien), le Méditerranéen II. (Helvétien-Tortonien) et par le Sarmatien, tandis que le Pliocène est représenté par tous les étages: Méotien, Pontien, Dacien et Levantin.

Après la phase du plissement principal mésocrétacé, la transgression du Crétacé supérieur s'étend sur la zone cristalline des Carpates Orientales. Les dépôts s'accumulent dans les bassins post-tectoniques de l'intérieur de la chaîne montagneuse. La dépression du Maramureș (au Nord des Carpates Orientales) se rattache au NW à la dépression Pannonienne, tandis que vers l'Est elle se continue dans le bassin de Borșa, au Nord-Ouest duquel se trouve la région Toroiaga, dont nous nous occupons.

A cet endroit la sédimentation débute par des conglomérats et des grès cénomaniens pour continuer avec des marnes turoniennes et sénoniennes. La submersion des bassins s'accentue graduellement, de sorte que la sédimentation continue durant le Paléogène; c'est alors que se déposent les couches éocènes et oligocènes. Nous assistons ensuite à l'exondation des bassins. Les

eaux se retirent progressivement vers l'ouest, vers la dépression Pannonienne et le bassin de Transylvanie.

Des bassins intramontagneux plus récents que ceux dont nous avons parlés se trouvent alignés dans la partie orientale de la chaîne carpatique et la séparent de la chaîne éruptive Călimani-Harghità. C'est dans ces bassins que se sont accumulés les dépôts pliocène-supérieurs, daciens, levantins et quaternaires.

La long de la partie occidentale des Carpates Orientales il y a eu durant le Tertiaire une intense activité volcanique, dont a résulté la chaîne éruptive

Fig. 1. Vue d'ensemble sur le massif de Toroiaga (Foto: A. Szőke)

Vihorlat-Harghità, qui vient compléter la structure — déjà compliquée — des Carpates Orientales.

La région Toroiaga est située dans la partie Nord des Carpates Orientales. Du point de vue géomorphologique, c'est une région montagneuse à altitudes entre 780 et 1931 mètres (Fig. 1).

Se trouvant dans le stade de jeunesse avancée, la région est fortement sillonnée par de nombreux cours d'eau permanents et par une série de ruisseaux torrentiels — causes du relief accidenté. On peut observer des traces glaciaires dans le Nord du massif. Le réseau hydrographique de la région est tributaire aux trois bassins principaux: la vallée de la Cisla, la vallée du Vaser et la vallée du Novăț.

La structure géologique de la région étudiée se compose d'un soubassement de schistes cristallins recouvert de dépôts sedimentaires d'âge crétacé supérieur et paléogène. Ce complexe de roches cristallines et sédimentaires a été percé, ultérieurement, par les éruptions néogènes.

Le soubassement des schistes cristallins appartient à la série d'épizone (Groupe II) du Cristallin des Carpates Orientales. Les schistes cristallins occupent toute la partie Nord-Est du périmètre; il n'y a qu'une zone étroite à l'Ouest et au Sud.

La plupart des schistes cristallins de la région sont des roches sédimentogènes, ayant pris naissance dans des conditions d'épizone, par le métamorphisme régional de certains sédiments argileux, gréseux et charbonneux, d'âge pré-carbonifère. Dans la phase précédant la métamorphisme, ces roches sédimentaires ont été traversées, par endroits, par des roches éruptives. C'est ainsi que se sont formées les porphyroïdes qui, d'après la structure et les minéraux reliques, semblent avoir été des porphyres quartz-dioritiques. Les reliques de plagioclases maclés, déterminés avec la table Fedorov, ont dévoilé un contenu d'An se chiffrant à 24—50%.

Nos études nous permettent de proposer la suivante classification des schistes cristallins du soubassement du massif de Toroiaga:

1. *Le complexe des schistes micacés.* Les roches de ce complexe sont très répandues dans la région. Suivant leur composition, nous avons distingué:

a) des schistes muscovitiques
b) des schistes séricito-chloriteux, quartzeux
c) des quartzites blancs-cendrés, compacts
d) des porphyroïdes
e) des calcaires cristallins
f) des brèches tectoniques

2. *Le complexe des quartzites noirs et des phyllites noirs* est beaucoup répandu. Les quartzites noirs constituent le terme supérieur des schistes cristallins de la région, tandis que les phyllites graphiteux se retrouvent également sous forme d'intercalations dans les schistes séricito-chloriteux. Elles ont une couleur noire, à intercalations de bandes et de lentilles de quartz blanc, résultées du métamorphisme régional de certains sédiments riches en matière charbonneuse.

Les dépôts sédimentaires mésozoïques et tertiaires sont représentés par des couches cénomaniennes et éocènes. Au Crétacé supérieur a lieu l'exondation de la dépression du Maramureş, dans la partie orientale de laquelle se trouve la région que nous étudions.

Le Cénomanien, qui représente la plus ancienne formation sédimentaire du périmètre étudié, n'occupe qu'un petit lambeau de Valea Ursului. Il repose transgressivement sur les schistes cristallins et supporte des formations éocènes. Les dépôts cénomaniens sont constitués par des grès massifs,pauvres en mica et

exempts de stratification. Ils sont de couleur blanche—blanche grisâtre, à taches rousses. A l'endroit indiqué, le grès cénomanien est fossilifère, il contient des exemplaires bien conservés d'*Exogyra columba*.

Eocène. La submersion de la dépression du Maramureș s'accentue durant l'Eocène, la sédimentation continue donc transgressivement sur les formations

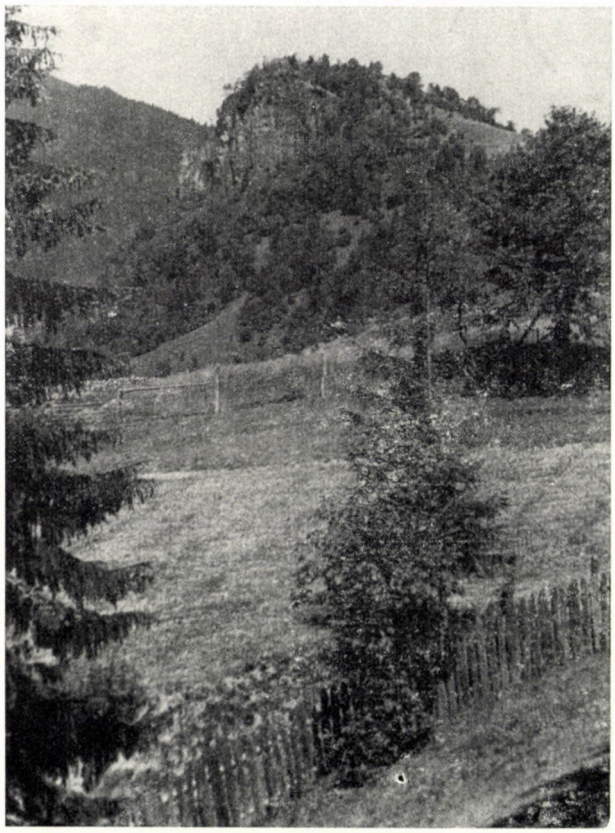

Fig. 2. Le rocher Piatra Băiții, formé de calcaires nummulitiques éocènes (Foto: A. Szőke)

crétacées ou directement sur des schistes cristallins. Les dépôts éocènes sont bien dévellopés dans les parties limitrophes de la région et se composent de marnes feuilletées, à couleur gris foncé, de bancs de grès et de calcaires nummulitiques (Fig. 2). Ces derniers reposent parfois directement sur les schistes cristallins (quartzites noirs). Ils sont fossilifères et contiennent des: *Nummulites striatus*, *N. incrassatus*, *Pecten* et *Asterocyclina stellata*.

Tectonique. La région étudiée est étroitement rattachée à l'orogène des Carpates Orientales. La direction générale NNW—SSE et le pendage Sud-

Ouest du soubassement des schistes cristallins correspondent à l'aspect général de la position des formations cristallines, dans les Carpates Orientales. Le processus de métamorphisme de ce complexe de roches a eu lieu probablement durant la formation du système calédonien.

Le chevauchement du Groupe I (mésozone) sur le Groupe II (épizone) a eu lieu durant la phase hercynienne de l'orogène carpatique.

Dès le Crétacé supérieur, la région est soumise à la transgression. Le bassin de Maramureș est graduellement submergé et devient un golfe de la Mer Pannonienne. La submersion continue durant le Tertiaire, les dépôts éocènes et oligocènes se déposent transgressivement sur le Crétacé, après quoi la mer se retire.

Durant le Néogène, le soubassement de la région ainsi que les dépôts sédimentaires ont été percés par le Massif éruptif de Toroiaga et la suite filonienne qui l'entoure. Après la consolidation du massif, le région a été affectée également par des mouvements tectoniques, dont ont résulté des fractures parallèles, orientées NE—SW, qui traversent le massif perpendiculairement sur son prolongement.

Historique

Les débuts des recherches géologiques exécutées dans cette région datent de la moitié du siècle dernier. Les premiers ouvrages ont aujourd'hui une importance plutôt historique et appartiennent à STRIPPELMANN (1855), B. VON COTTA (1855) et GESELL (1881). Ces trois auteurs décrivent la minéralisation de la région.

L'ouvrage le plus précieux du siècle dernier appartient à ZAPALOWICZ (1886), qui décrit d'une manière assez détaillée les formations sédimentaires des environs du massif éruptif. C'est toujours lui qui a dressé la première carte géologique de la région.

Beaucoup plus tard, après une pause de presqu'un demi-siècle, l'attention des chercheurs s'arrête de nouveau sur le massif de Toroiaga. Les géologues KAMIEŃSKI (1935), TOKODY (1939), FÖLDVÁRY et PANTÓ (1946) s'occupent surtout de l'étude des roches et de la minéralisation.

Après la seconde guerre mondiale, les recherches géologiques prennent un grand essor dans la région que nous étudions. Les ouvrages systématiques de prospections et d'explorations sont dirigés par le Comité Géologique. Dans cette période, les premiers ouvrages publiés sont signés par SOCOLESCU (1948—1949), qui établit la structure générale de la région Toroiaga, dresse une carte géologique à l'échelle 1 : 20 000 et trace les directives des recherches ultérieures.

Durant les années qui suivent (1950—1954), DIMITRESCU élabore aussi une carte géologique à l'échelle 1 : 20 000 détaillant les formations sédimentaires, et une autre carte à l'échelle 1:10 000, à caractère structural. Avec

PATRULIUS et BLEAHU il étudie surtout les roches porphyrogènes et les dépôts sédimentaires.

Depuis 1954 et jusqu'à présent la région Toroiaga est étudiée par SZŐKE [19,20,21]. L'auteur s'occupe en détail du massif éruptif, en déchiffrant sa structure pétrographique. Les résultats principaux sont exposés dans le présent article.

Roches éruptives

Les roches éruptives du massif de Toroiaga appartiennent à la série des éruptions tertiaires, localisées dans la partie Ouest de l'arc des Carpates Orientales. Cette chaîne éruptive a été mise en place le long de la zone de fracture, à direction NW—SE, qui a pris naissance entre le Cristallin des Carpates Orientales et le bassin de la Transylvanie, respectivement la dépression Pannonienne, à cause de la submersion de ces derniers. Une intense activité volcanique eut lieu le long de cette ligne tectonique, durant le Tertiaire; c'est ainsi que prit naissance la chaîne commençant au NE avec les Monts Vihorlat, Gutin, Ţibleş, Toroiaga, Rodna, Bîrgău et continuant au SE avec les imposants cônes volcaniques des Monts Călimani, Gurghiu et Harghità.

L'appareil des volcans autrefois actifs de la chaîne susmentionée se compose d'alternances, de coulées de lave et d'agglomérats, fait qui prouve que ces volcans ont eu jadis une activité mixte.

A l'encontre des autres régions de la chaîne éruptive Vihorlat-Harghità, dans le massif de Toroiaga les éruptions tertiaires sont représentées exclusivement par des corps subvolcaniques. Les produits de la phase effusive manquent totalement.

L'ensemble éruptif forme un corps intrusif, de forme allongée, irrégulière; il est entouré d'une zone d'apophyses, représentée par des dykes et des sills (Fig. 3). La direction d'allongement du subvolcan coïncide en grandes lignes avec la position des schistes cristallins. Vers le NW, le corps éruptif s'élargit graduellement, tandis que vers le SE il se retrécit et accuse une forme digitée.

Les apophyses andésitiques qui accompagnent le massif principal ont pénétré dans les roches encaissantes suivant les directions de faible résistance tectonique. Si l'on poursuit ces lignes on voit qu'elles peuvent avoir une position concordante (sills) soit une position discordante (dykes) par rapport aux formations cristallines et sédimentaires traversées.

Le massif subvolcanique de Toroiaga s'est consolidé sous une couverture de schistes cristallins, aujourd'hui en grande partie enlevée par l'érosion, mais dont les traces ont été identifiées dans plusieurs points de la région (voir le bloc-diagramme ci-joint). Ces lambeaux de schistes cristallins marquent la région périphérique et de couverture du corps éruptif. C'est à eux que se rattachent les brèches andésitiques et les produits des phénomènes pneumato-

lytiques et hydrothermaux, représentés par des zones de tourmalinisation, sur lesquelles nous reviendrons.

Nous avons constaté que les andésites à hornblende et à biotite sont les roches les plus répandues de la région. Moins fréquentes sont les diorites quartzifères, les brèches andésitiques et les aplites.

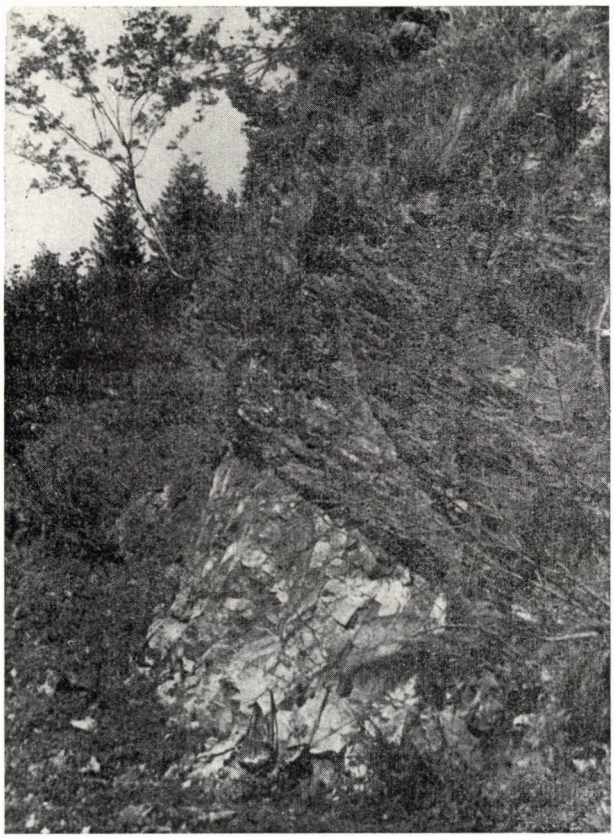

Fig. 3. Sill andésitique dans Valea Secului (Foto: A. Szőke)

A l'intérieur du massif principal nous avons réussi à identifier trois apparitions de roches à structure granulaire, représentées par des diorites quartzifères, qui forment le noyau du massif. La plus importante est située dans Valea Murgu et les deux autres dans Valea Novăţ. Il est à supposer que ces apparitions qui sembleraient isolées, continuent dans les profondeurs et se joignent, de manière à former un seul corps qui représente le facies de profondeur du subvolcan de Toroiaga. Les diorites quartzifères se trouvent toujours dans les parties inférieures du massif et n'affleurent que dans les vallées fortement creusées du massif.

La transition des roches du faciès de profondeur aux roches andésitiques est réalisée par une série de porphyres dioritiques quartzifères (Fig. 6, 7, 8 et 9). Sur le terrain, ils se groupent toujours autour des diorites quartzifères. Vers les parties superficielles, les porphyres dioritiques passent graduellement à des andésites à hornblende et à biotite. Ce sont au début des andésites à pâte macrogranulaire (Fig. 10) qui passent graduellement à des andésites microcristallines (Fig. 11) et cryptocristallines (Fig. 12) et enfin, à proximité de l'ancienne couverture cristalline, à des andésites demi-vitreuses (Fig. 13). Nous avons essayé, dans le bloc-diagramme ci-joint, de représenter cette situation, idéale à sa manière, de passage graduel depuis la structure granulaire jusqu'à la structure porphyrique demi-vitreuse (Fig. 18).

Parmi les roches qui forment le massif subvolcanique et la suite filonienne qui l'entoure les plus fréquentes sont les andésites à hornblende et à biotite. Macroscopiquement, les divers types d'andésites se différencient par la couleur et par les dimensions relatives des minéraux composants. La plupart sont de couleur grise. Les andésites noires sont limitées; les variétés riches en biotite prennent une nuance violacée.

Nous avons identifié, pour la première fois, les andésites brécheuses de cette région. Nous avons déjà signalé qu'on les rencontre régulièrement audessous des lambeaux de schistes cristallins de l'ancienne couverture du massif et qu'elles ont pris naissance par suite de l'effort mécanique réciproque entre le magma en ascension et les schistes cristallins environnants. Ces roches nous aident à reconstituer en quelque mesure la forme initiale et les conditions de formation du subvolcan.

Suivant nos études microscopiques nous avons constaté que les roches du massif de Toroiaga sont formées de minéraux principaux suivants: le plagioclase, l'orthose, la hornblende verte et, moins souvent basaltique, le biotite. Les minéraux accessoires sont: l'apatite, le rutile et le zircon. Par la transformation des minéraux principaux prennent naissance: la séricite, le kaolin, la chlorite, la calcite et l'épidote.

Les plagioclases se présentent sous forme de phénocristaux et de microlithes dans les andésites; de même, ils constituent l'élément principal dans les diorites quartzifères. Les phénocristaux ont en général des contours cristallographiques nets (dans les andésites et dacites) et parfois irréguliers (dans certains diorites quartzifères). Les plagioclases maclés des diorites quartzifères ont un contenu en An qui varie de 45 à 55%. La fréquence des lois de macle, exprimée en pourcentages, est la suivante: Karlsbad 30%, Albite 28%, Albite-Ala 24%, Albite-Karlsbad 16%, Aclin-Manebach-Ala 2%.

Les valeurs des angles 2V de ces plagioclases varient de 79° à 86°.

Les déterminations effectuées par la méthode de la table universelle Fedorov sur les plagioclases zonés des diorites quartzifères montrent que le contenu en An est plus variable (33—80%) que chez les individus non-zonés,

mais la moyenne se maintient toujours autour de 50%, comme pour les plagioclases zonés. Les diagrammes de variation du contenu en An pour les plagioclases zonés font encore voir qu'en général le noyau est plus acide, tandis que la zone [19] périphérique ou certaines zones intermédiaires sont plus basiques. Cette composition est souvent soulignée par les inclusions secondaires, dont la formation commence toujours dans les zones plus basiques.

Le contenu en An % des phénocristaux maclés des divers types d'andésites varie aussi de 30—60%.

Les angles 2V mesurés varient de 77° à 88°.

Les diagrammes de variation du contenu en An des plagioclases montrent qu'il existe plusieurs types de plagioclases à structure zonée, dont la plupart ont le noyau plus acide et des zones marginales basiques. Là encore le contenu en An varie entre des limites beaucoup plus larges (34—75%) que pour les plagioclases maclés. Nous mentionnons que les zones basiques sont en général très minces, de sorte que la composition moyenne de ces minéraux ne dépasse pas le contenu en An des plagioclases non-zonés.

L'orthose est très peu répandue dans les roches étudiées. Elle existe sous forme de phénocristaux dans les dacites et forme des enchevêtrements aves le quartz dans les diorites quartzifères et dans les aplites.

Le quartz est fréquent dans les roches de Toroiaga. Il constitue des phénocristaux dans les dacites et des microlites dans la pâte des andésites.

Les amphiboles, étant des mineraux mélanocrates prédominants sont présents dans tous les types de roches. Ils forment des phénocristaux prismatiques très allongés, au module d'allongement variant de 1 : 16 à 1 : 12. Les hornblendes communes vertes, à pléochroïsme intense: n_g vert-olive, n_m vert, n_p jaune, légèrement verdâtre sont les plus fréquentes. L'angle d'extinction $c : n_g$ est en général 17°—18°, rarement 22°. Il y a souvent des macles simples ou polisynthétiques, d'après la face (100).

La hornblende bazaltique est peu fréquente dans les roches de Toroiaga. Son angle d'extinction $c : n_g = 9° - 10°$. Elle présente un pléochroïsme accentué: n_g = brun foncé, allant parfois jusqu'au noir, n_p = jaune paille ou jaune foncé. Elle contient des inclusions d'apatite, de zircon, de plagioclases, des minéraux opaques et souvent des séparations de sagenite.

La structure et la texture des roches éruptives de Toroiaga est assez variée. La variation structurale des roches d'une part et leur uniformité minéralogique de l'autre, nous ont poussé à classifier ces roches suivant des critères de structure. Les principaux types de structures — notons que l'on peut observer toute la gamme des structures de transition — sont les suivants:

1. *Structures granulaires* dans les roches à caractère de profondeur.

2. *Structures porphyriques.* Ce sont les plus fréquentes dans le massif étudié et apparaissent dans toutes les andésites et les dacites. Les structures porphyriques diffèrent par la variation de la pâte qui accuse des transitions

imperceptibles depuis la structure holocristalline à grande granulation jusqu'à la structure hypocristalline.

La variation des structures est due aux conditions de formation et surtout à la profondeur différente où ces roches ont pris naissance. La vitesse de refroidissement, en fonction autant de la profondeur que de la distance jusqu'aux roches encaissantes n'est pas égale dans les différentes parties de la masse magmatique; c'est pourquoi elle a une influence capitale sur la formation des structures. C'est ainsi que s'explique cette gamme variée de structure, allant de la structure holocristalline équigranulaire de profondeur jusqu'à la structure hypocristalline porphyrique demi-vitreuse, aux parties supérieures du massif. En général nous considérons que la profondeur à laquelle a eu lieu le processus de consolidation du massif Toroiaga n'a pas été trop grande (tout au plus 1000 m), car les roches à structure granulaire sont relativement peu répandues, tandis que prédominent les roches porphyriques.

Lors de la classification des roches éruptives suivant les caractères structuraux, nous avons tenu compte de la structure, des dimensions relatives des minéraux, de la quantité et de la nature de la pâte. Ainsi nous avons distingué:

1. Des diorites quartzifères et des porphyres dioritiques quartzifères.
2. Des andésites à hornblende et à biotite.
   - *a)* Andesites à pâte macrogranulaire
   - *b)* Andesites à pâte microgranulaire
     - *α)* „ „ „ „ leucocrate
     - *β)* „ „ „ „ mélanocrate
   - *c)* Andésites à pâte cryptocristalline
   - *d)* Andesites à pâte hypocristalline
3. Andésites brécheuses
4. Dacites
5. Aplites

1. *Diorites quartzifères.* La représentation sur le triangle de JOHANNSEN des résultats obtenus par des mesures planimétriques montre que ces roches appartiennent au domaine des diorites quartzifères.

Les plagioclases de ces roches ont un contenu en An variant de 44 à 55%. En général le contour des minéraux est irrégulier, à cause de leur interpénétration. On y trouve de l'orthose, mais en moindre quantité, tandis que le quartz en grains xénomorphes est assez abondant. Parmi les minéraux mélanocrates, il y a la hornblende verte et la biotite. En général la roche est imprégnée de pyrite et très souvent traversée de petits filons remplis d'épidote. Parmi les minéraux secondaires, nous mentionnons: la chlorite (clinochlore et pennine), la séricite et l'épidote.

2. *Les andésites à hornblende et à biotite.* Lorsque nous avons séparé les types d'andésites, nous avons tenu compte autant de la nature de la pâte (dimension et nature des microlithes) que de son pourcentage par rapport à la quantité totale des phénocristaux. Nous avons distingué:

a) *Des andésites à pâte macrogranulaire* (Fig. 10) qui font la transition naturelle, structurale, des porphyres dioritiques quartzifères aux andésites proprement dites; elles ressemblent aux premières par les grandes dimensions des microlithes et aux andésites par la quantité élevée de pâte, qui dans les cas extrêmes, constitue jusqu'à 55% de la masse de la roche.

Le contenu en An des phénocristaux de plagioclase varie de 40 à 60%, et celui des microlithes de 45 à 50%. Les minéraux mélanocrates sont la hornblende verte et la biotite.

b) *Les andésites à pâte microgranulaire* ont été séparées en deux types distincts:

α) *Andésites à pâte microgranulaire leucocrate:* ce sont les roches les plus fréquentes du massif de Toroiaga. Elles ont une structure porphyrique holocristalline et une texture massive. La quantité de la pâte atteint 39 jusqu'à 58%; elle est holocristalline, microgranulaire, formée en grande partie de granules izométriques, xenomorphes, de quartz, plagioclases et fragments de minéraux colorés et opaques.

β) *Andésites à pâte microgranulaire mélanocrate;* elles sont moins fréquentes dans la région et correspondent aux andésites noires dont nous avons déjà parlé. Elles se distinguent facilement au microscope des andésites précédentes, par leur pâte formée de microlites prismatiques de hornblende verte, à dimensions micromères, à disposition légèrement fluidale, parmi lesquelles on observe des grains isométriques de magnétite, finement dispersée dans la pâte de la roche. En ce qui concerne les phénocristaux, on les distingue des andésites à pâte leucocrate, par le fait qu'à part la hornblende verte, elles contiennent également de la hornblende basaltique.

Sous forme de phénocristaux apparaissent aussi les plagioclases avec un contenu en anortite s'élevant à 45—52%. Ils sont maclés polisynthétiquement, d'après les lois: Albite, Karlsbad et Albite-Karlsbad, ou zonés avec plusieurs récurrences. Ils sont en général entourés d'une couronne de réaction.

c) *Les andésites à pâte cryptocristalline* ne se distinguent pas minéralogiquement des précédentes. La pâte est cryptocristalline et sa quantité atteint des pourcentages très élevés jusqu'à 67%.

d) *Les andésites à pâte hypocristalline* sont très peu répandues à Toroiaga. Elles se retrouvent aux parties supérieures du massif et constituent une partie des crêtes les plus élevées. Ce sont des roches très altérées, à phénocristaux totalement transformés en produits secondaires: séricite, kaolin, calcite, etc. La pâte de la roche est formée d'un verre amorphe, qui englobe des microlites

de plagioclases altérés, des pseudomorphoses de chlorite, des grains de quartz et de minéraux opaques.

3. *Les andésites brécheuses.* Nous avons déjà montré que les andésites brécheuses constituent un faciès marginal du massif de Toroiaga. Elles sont formées de fragments plus ou moins anguleux d'andésites à pâte vitreuse, à couleur foncée, qui ne s'associent que par endroits à des morceaux de roches sédimentaires ou de schistes cristallins. Les brèches sont toujours très altérées, vu que les solutions hydrothermales ont circulé facilement entre les fragments.

4. Dans les *dacites*, à part les minéraux décrits déjà chez les andésites apparaissent encore des phénocristaux d'orthose et de quartz. Ce dernier est en général fortement corrodé. L'orthose se retrouve dans les quantités très variées, parfois en quantité égale au plagioclase. Les éléments mélanocrates sont représentés par la hornblende verte et la biotite. La pâte de ces roches est généralement cryptocristalline ou très rarement microgranulaire.

5. *Les aplites* forment de petits filons à diamètres centimétriques, englobés dans des andésites et des diorites quartzifères. Elles ont une couleur blanche-rose. Leur structure est holocristalline, panallotriomorphe, grenue. Les aplites sont constituées par le quartz, l'orthose, le plagioclase, très peu de biotite, des minéraux secondaires et des minéraux opaques.

Considérations sur le chimisme des roches éruptives

Afin de caractériser la composition chimique, nous avons exécuté 7 analyses des principaux types de roches éruptives du massif de Toroiaga (Tableau 1). Le Tableau 2 comprend le total des valeurs NIGGLI et le Tableau 3 établit le pourcentage de minéraux normatifs, calculé d'après ces analyses chimiques.

Il en résulte que l'acidité des roches étudiées est assez uniforme. Les valeurs *qz* renvoient la roche dans la catégorie des magmas acides. Le type magmatique est monzonitique et quartz-dioritique (Fig. 4). En figurant les résultats des mesures planimétriques sur le diagramme tétraédrique de variation du contenu en quartz, orthose et plagioclases de JOHANNSEN, nous observons qu'ils se groupent dans le champ qui détermine la composition du diorit quartzifère (Fig. 5).

Le diagramme de différenciation ainsi que les autres diagrammes montrent clairement que les roches étudiées sont très peu différenciées. Par conséquent les conclusions auxquelles nous avons abouti à l'aide des études microscopiques se trouvent confirmées par les analyses chimiques. Les deux établissent que, dans le massif de Toroiaga, les roches varient du point de vue structural, tandis que les différences chimiques sont presque insignifiantes.

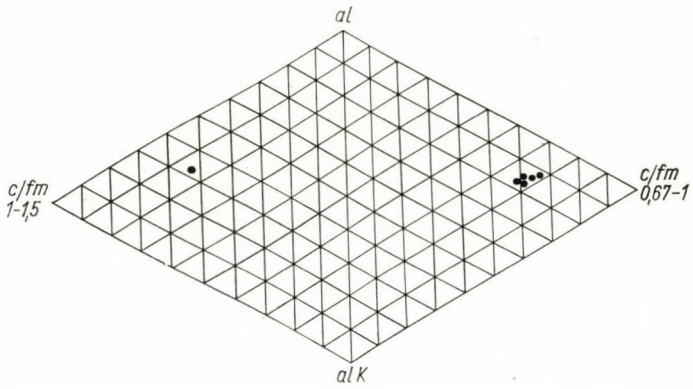

Fig. 4. La représentation des roches éruptives du massif de Toroiaga sur le tetraèdre de concentration de NIGGLI

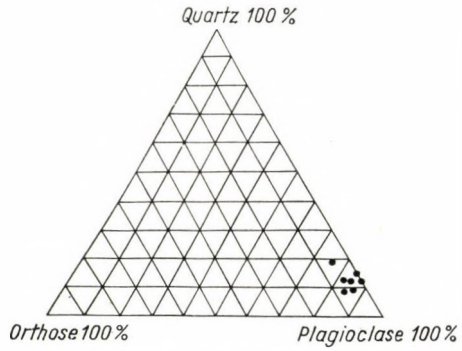

Fig. 5. Le diagramme de variation du contenu en quartz, orthose et plagioclase, d'après la méthode de JOHANNSEN

Processus pneumatolytiques et hydrothermaux

L'activité magmatique de la région étudiée se manifeste aussi dans les phases plus tardives, par des solutions minéralisatrices. Ces processus ont affecté les roches éruptives ainsi que les formations environnantes. S'adaptant aux nouvelles conditions crées par la présence des solutions, la paragenèse liquide-magmatique est remplacée graduellement par une autre paragenèse, qui contient du chlorite, de l'épidote, de la calcite et des minéraux opaques.

Les phénomènes d'autométamorphisme hydrothermal du massif de Toroiaga se sont manifestés dans des zones bien délimitées, accompagnant les filons métallifères et les lignes tectoniques non-minéralisées de la région. Ce mode d'apparition des zones propilitisées dans la région témoigne clairement leur origine hydrothermale.

Les roches transformées sous l'action des solutions hydrothermales sont en général assez facilement reconnues suivant leur aspect extérieur. Elles deviennent plus dures et plus compactes, leur couleur change en fonction des minéraux prédominants ou nouvellement formés; elles deviennent verdâtres (roches propilitisées) vert-jaunâtre (épidotisées), blanche ou blanc-grisâtre (roches silicifiées) ou blanc-farineuses (roches kaolinisées).

La transformation des roches se produit graduellement, de sorte que nous avons la possibilité d'observer le phénomène depuis la phase initiale jusqu'à la phase finale. Nous avons constaté ainsi que la substitution de la hornblende par des paillettes de biotite s'était produite dans un stade caractérisé par une température relativement élevée, lorsque la hornblende n'était pas encore altérée.

Avec la baisse graduelle de la température, nous assistons premièrement à la substitution de la hornblende et ensuite de la biotite, par la chlorite, associée à des minéraux opaques. La substitution commence toujours aux bords du cristal et dans les directions de clivage. A ce moment, les feldspaths, plus refractaires, résistent mieux à l'action de la solution et restent non-altérés. Leur transformation en séricite (Fig. 14) et ensuite en kaolin commence en général plus tard, lorsque les minéraux mélanocrates sont déjà totalement remplacés par une pseudomorphose de chlorite. Parfois la hornblende se transforme en une variété fibro-radiaire (Fig. 16).

La calcification peut avoir lieu soit par la libération du calcium des plagioclases, soit par un apport de calcium, obtenu de la solution hydrothermale. Les plaques minces étudiées nous ont fourni des exemples des deux cas. Pour le premier, la calcite de néo-formation ne dépasse pas le contour du minéral aux dépens duquel il se forme, tandis que dans le second cas la calcite constitue des infiltrations à contour irrégulier dans la pâte de la roche, ou dans les phénocristaux. L'épidote peut se former autant aux dépens de la hornblende que du plagioclase, mais il se dépose aussi dans les fissures de la roche, où il forme des filonnets (Fig. 15).

La kaolinisation marque toujours la baisse considerable de la température et en même temps un stade avancé du processus de transformation. Lorsque les plagioclases sont complètement remplacés par des produits secondaires, la chlorite, formée aux dépens des mélanocrates, dépasse le contour des minéraux- hôtes et entraînée par les solutions, se répand dans toute la masse de la roche.

La phase la plus avancée du processus — la phase finale —, se caractérise par la transformation totale de la roche en une masse kaolino-quartzeuse, de couleur blanc-grisâtre, ou jaunâtre, à aspect terreux. Les salbandes des filons métallifères sont généralement constitués par cette masse amorphe, kaolineuse.

Grâce à la circulation des solutions hydrothermales dans les fissures plus larges du massif, se sont déposés les minéraux métallifères suivants: pyrite, chalcopyrite, sphalérite, galène, mispikel, tétraédrite, plumosite, pyrrhotine, semseyite, bournonite, marcasite, associés au quartz, à la calcite et à la dolomite.

La mise en place du massif éruptif a provoqué certaines transformations également dans les formations encaissantes où il a pénétré. Ainsi, au contact les roches sédimentaires, ont subi de légères transformations caustiques et des plissotements locaux. Plus importants sont les changements subis par les schistes cristallins qui se trouvent en contact avec le corps éruptif principal. Nous y avons constaté l'existence des zones de tourmalinisation (Fig. 17) qui se rattachent aux parties marginales et supérieures du massif et se manifestent surtout dans les andésites brécheuses et dans les restes de schistes cristallins, conservés de la couverture du corps éruptif. La tourmaline a pris naissance à la suite de l'apport de bore, fourni par le magma dans la phase pneumatolytique. La silicification des roches de contact est également considérable, étant due à l'apport de silice fourni par le magma.

Tableau 1

Analyse chimique des roches éruptives du massif de Toroiaga

	1.	2.	3.	4.	5.	6.	7.
SiO_2	59,84	59,84	59,80	59,60	59,53	59,27	59,20
Al_2O_3	16,45	15,96	16,50	15,81	16,70	16,14	16,61
Fe_2O_3	1,47	1,78	2,50	3,01	3,91	2,97	4,87
FeO	4,60	4,39	3,50	3,11	1,07	3,20	2,75
Fe	—	—	—	0,41	0,21	0,43	—
TiO_2	0,73	0,58	0,82	0,70	0,69	0,69	0,68
MnO	0,10	0,12	0,10	0,11	0,09	0,10	0,10
MgO	2,50	2,29	3,20	2,99	2,75	2,84	3,00
CaO	5,90	5,65	6,60	6,18	7,50	6,22	5,87
Na_2O	3,40	3,74	3,80	3,26	4,70	3,40	3,23
K_2O	2,90	2,99	1,24	2,26	0,66	2,24	3,00
F_2O_3	0,12	0,16	0,20	0,21	0,19	0,19	0,19
S	traces	traces	traces	0,47	0,25	0,50	—
$H_2O + 105^0$ C	0,94	1,02	0,95	1,37	1,10	1,42	0,67
CO_2	1,26	1,20	1,03	0,75	0,60	0,75	—
Total	100,21	99,72	100,24	100,24	99,95	100,36	100,17
Roche	Andésite	Andésite	Diorite quartzifère	Andésite	Andésite	Andésite	Diorite quartzifère

Tableau 2

Valeurs Niggli des roches éruptives au massif de Toroiaga

Valeurs	1.	2.	3.	4.	5.	6.	7.
si	200,80	197,81	192,27	199,79	193,75	197,59	187,45
al	32,39	30,95	31,37	31,18	32,03	31,66	30,98
fm	29,17	30,75	31,27	31,38	25,78	30,46	33,07
c	21,12	20,04	22,77	22,13	26,17	22,24	19,96
alk	17,30	18,25	14,67	15,29	16,01	15,63	15,96
k	0,36	0,34	0,19	0,31	0,07	0,29	0,38
mg	0,42	0,36	0,49	0,46	0,43	0,46	0,43
c/fm	0,72	0,65	0,72	0,73	1,01	0,76	0,60
qz	+31,60	+24,81	+33,59	+38,63	+29,71	+35,07	+23,61
Ls	0,66	0,68	0,63	0,61	0,66	0,63	0,67
Fa	0,17	0,19	0,16	0,18	0,18	0,18	0,20
Qs	0,15	0,12	0,17	0,19	0,15	0,17	0,19
ti	1,81	1,38	1,93	1,81	1,75	1,80	1,33
p	0,20	0,19	0,19	0,20	0,19	0,20	0,57
Type magmatique	monzonitique						quartz dioritique

Tableau 3

Minéraux normatifs (d'après le système C.I.P.W.)

	1.	2.	3.	4.	5.	6.	7.
Q	15,41	14,53	16,23	14,73	13,51	16,64	14,58
Or	18,52	19,83	7,87	12,90	3,27	12,44	17,31
Ab	32,30	33,37	32,14	27,96	40,67	29,81	28,39
An	21,95	0,08	22,66	27,75	21,99	21,77	21,68
Mo	4,05	13,53	3,69	0,51	6,58	3,68	2,19
En	9,16	7,92	10,54	9,94	9,13	9,28	10,16
Mt	1,34	1,51	2,09	2,53	0,80	2,44	3,94
Ap	0,29	0,27	0,26	0,26	0,26	0,27	0,85
Es	5,56	8,05	2,96	2,15	2,53	2,44	0,29
Il	1,34	0,96	1,31	1,19	1,20	1,20	1,08

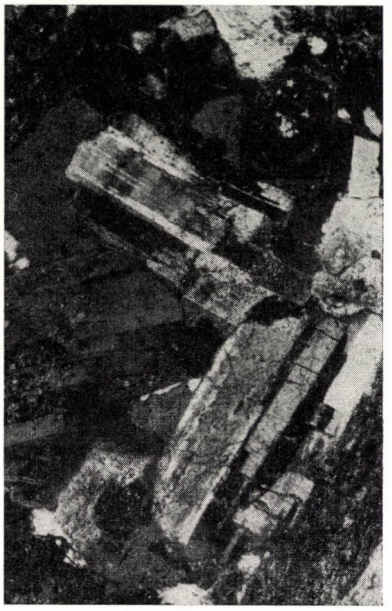

Fig. 6. Structure holocristalline équigranulaire. Diorite quartzifère. Valée Margu, Toroiaga. Nicols +20×

Fig. 7. Structure holocristalline à enchevêtrements myrmékitiques. Diorite quartzifère, Valée Murgu, Toroiaga. Nicols +20×

Fig. 8. Structure holocristalline inéquigranulaire. Nicols + 20×

Fig. 9. Texture orientée d'un porphyre-dioritique quartzifère. Valea Novăţ, Toroiaga. Nicols +20×

Fig. 10. Structure porphyrique à pâte holocristalline macrogranulaire. Andésite à hornblende et à biotite. Nicols + 20×

Fig. 11. Structure porphyrique à pâte microgranulaire. Andésite. Nicols + 20×

Fig. 12. Structure porphyrique à pâte cryptocristalline. Nicols + 20×

Fig. 13. Plagioclase zoné dans l'andésite. Nicols + 20×

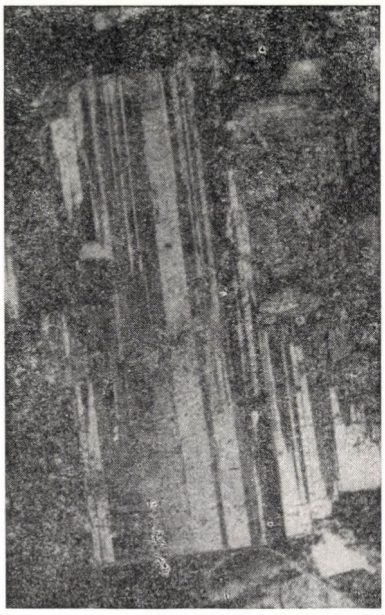

Fig. 14. Plagioclase à début de transformation en séricite et en kaolin. Andésite, Toroiaga. Nicols + 50×

Fig. 15. Epidote, cristallisé dans les fissures du diorite quartzifère, Valea Murgu, Toroiaga. Nicols + 50×

Fig. 16. Hornblende, fibro-radiaire, d'origine secondaire, dans l'andésite altérée. Nicols + 100×

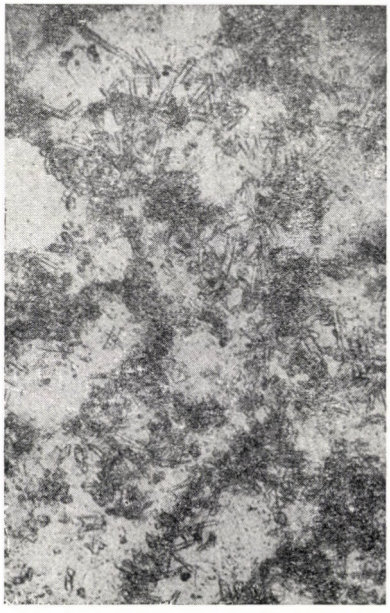

Fig. 17. Cristaux aciculaires de tourmaline dans des cornéennes. Nicols + 150×

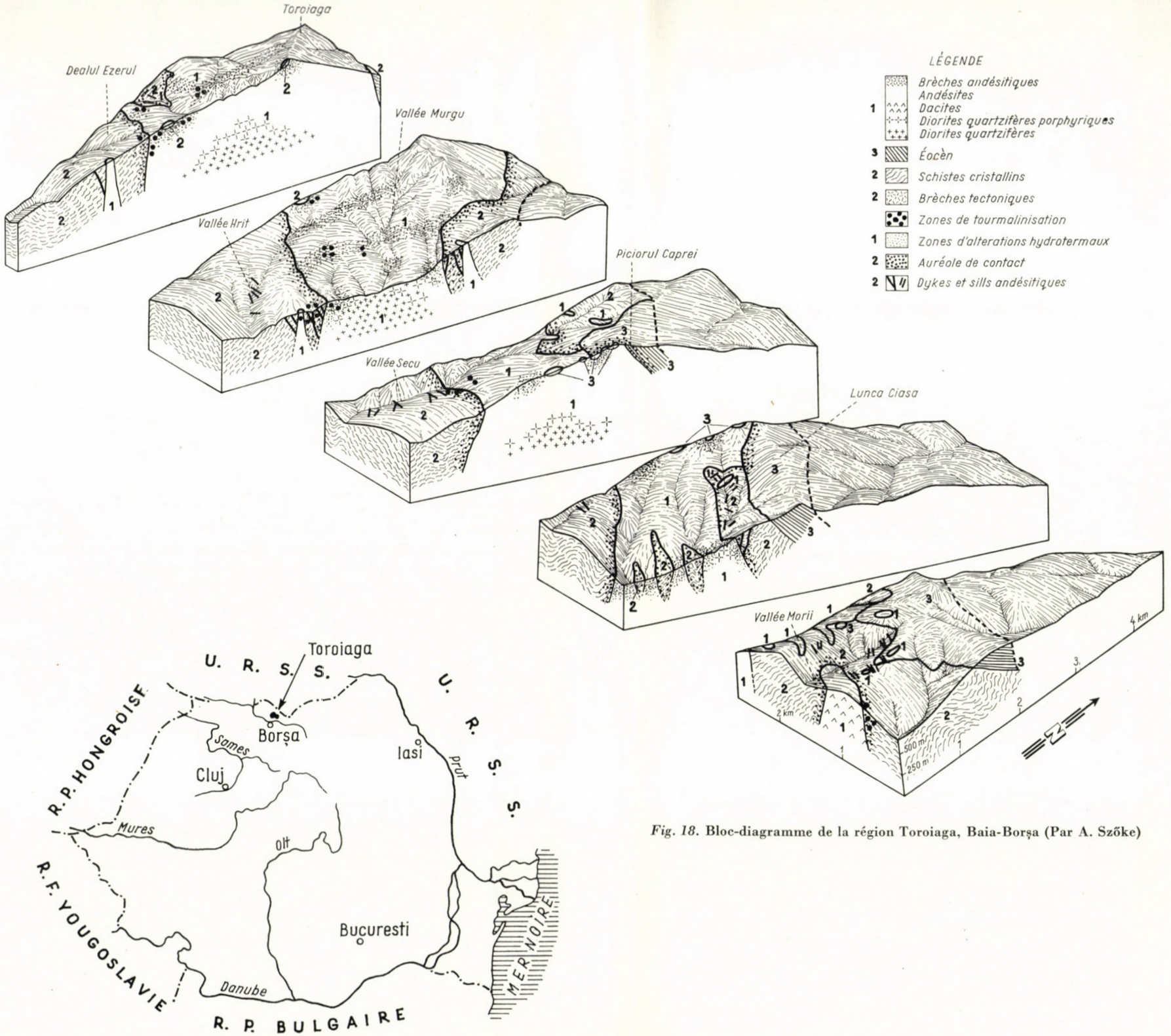

Fig. 18. Bloc-diagramme de la région Toroiaga, Baia-Borşa (Par A. Szőke)

BIBLIOGRAPHIE

1. BĂNCILĂ, I.: Geologia Carpaţilor Orientali (Edition Scientifique, Bucarest, 1958. — 2. COTTA, B. von: Die Erzlagerstätten der südlichen Bukowina. Jahrb. d. k. k. Geol. Reichsanstalt, **6,** 1855. — 3. DIMITRESCU, R.: Cercetări geologice în regiunea Baia-Borşa, Toroiaga. Dări de seamă ale şed. Com. Geol. **XXXIX,** 1951—52, Bucarest, 1955. — 4. DIMITRESCU, R.: Cercetări petrografice în regiunea Baia-Borşa, Toroiaga. Dări de seamă ale şed. Comit. Geol. **XXXIX,** 1951—52, Bucarest, 1955. — 5. FÖLDVÁRI, A. et PANTÓ, G.: Bányageológiai megfigyelések Borsabánya, az Aranyosbeszterce völgy és Gyergyótölgyes környékének ércelőfordulásain és néhány más erdélyi ásványlelőhelyről. MÁFI Évi Jel. 1941—42-ről. — 6. GESELL, S.: Geologia judeţului Maramureş cu considerare specială asupra zăcămintelor de minerale utile. Almanahul Soc. Carpaţi din Ungaria, **VIII,** 1881. — 7. KRÄUTNER, Th.: Observation géologique et pétrographique dans le massif cristallin du Maramureş. C. R. Inst. Geol. Rom. **XXIII,** 1934—35, 1940. — 8. KAMIEŃSKI, M.: Bemerkungen über die Andesite des Torojaga-Gebietes in den Marmaroscher Karpaten. Bull. de l'Academie Polonaise, Serie: Sc. Mat. Cracovia, 1935. — 9. MURATOV, M. V.: Tectonica U. R. S. S. (traduction fragmentaire d'après l'édition.: Izd. A. N. SSSR, Moscou—Leningrad 1949). — 10. PANTÓ, G.: A Borsabánya melletti Torojága szulfidos érctelérei. MÁFI Évi Jel. **VIII,** 1946. — 11. PANTÓ, G.: Szfalerit-kalkopirit rendszerek a Torojága-i Mihály-telér (Borsabánya) ércéből. MÁFI Évi Jel. **VIII,** 1946. — 12. PATRULIUS, D.—DIMITRESCU, R.—BLEAHU, M.: Cercetări geologice în valea Vişăului şi în regiunile Săcelului (Maramureş). Dări de seamă ale şed. Com. Geol. **XXXIX,** Bucarest, 1952. — 13. POLOVINCHINA, U. I.: Structuri gornîh porod. Gozgeolizdat. Moscou, 1948. — 14. SAVUL, M.— MASTACAN, G.: Contribuţii la cunoaşterea gnaiselor porfiroide din Carpaţii Orientali. Bul. Şt. Secţ. Şt. Biol. Agron. Geol. şi Geogr. **IV,** 2, 1952. — 15. SOBOLEV, V. et collaborateurs: Petrografia neogenovîh vulkaniceskih i gipabissalnîh porod sovetschih Carpat. Izdatelstvo Nauk. Ukrainskoi SSR. Kiev. 1955. — 16. SOCOLESCU, M.: Asupra geologiei regiunii Baia-Borşa. Dări de seamă ale şed. Inst. Geol. Rom. **XXXVI,** 1948—49, Bucarest, 1952. — 17. STRIPPELMANN, L.: Observaţiuni asupra ocurenţei filoanelor metalifere în Muntele Toroiaga, la Borşa în Ungaria. Österreichische Zeitschrift für Berg- und Hüttenwesen. Dritter Jahrgang 1855. — 18. SZÁDECZKY-KARDOSS, E.: A vulkáni hegységek kutatásának néhány alapkérdéséről. Földt. Közl. **LXXX,** 8, 1958. — 19. SZŐKE, A.: Studiu asupra plagioclazilor din masivul subvulcanic de la Toroiaga, Baia-Borşa. Studii şi cercetări de Geol-Geogr. Acad. RPR. Nr. 1. Bucarest, 1960. — 20. SZŐKE, A.: Studiul geologic şi petrografic al regiunii Toroiaga, Baia-Borşa. (Dizertaţion.) Bucureşti, Edit. Acad. RPR. 1962. — 21. SZŐKE, A.: Studii structurale petrologice in masivul subvulcanic Toroiaga, Baia-Borşa. Studii şi cercetări de Geol. ale Acad. RPR. Nr. 3—4. Bucureşti, 1962. — 22. TÖRÖK, Z.: Problemele teoretice şi practice ale metodei faciesurilor complexe. Studii şi cercetări ale Acad. RPR. filiala Cluj. 1956. — 23. TRUSOVA, F. J.: Rocile metamorfice ale masivului Rahov Analele Romîno-Sovietice, Nr. 5, Bucureşti, 1953. — 24. ZAPALOWICZ, H.: Eine geologische Skizze des Oestlichen Teiles des Pokutisch—Marmaroscher Grenzkarpathen. Jahrbuch k. k. Wien, 1886.

THE LITHOLOGY OF THE TOROIAGA SUBVOLCANIC MASSIF

By

A. SZŐKE

Abstract

The Toroiaga (Borsabánya) subvolcano, constituting the southernmost part of the Máramaros mountain area, was organically connected with the Tertiary volcanic range extending on the inner side of the East Carpathian arc.

Its environment is formed by epizonal crystalline slates (sericite and chlorite slates, porphyroids, dark quartzites, etc.) overlain by the Upper Cretaceous, Eocene and Oligocene sediments of the Máramaros basin. The bulk of the biotitic amphiboleandesite subvolcano consists of an irregularly outlined mass elongated in NW—SE direction, surrounded by a similarly andesitic dyke-system.

The subvolcanic character of the magmatic mass is fully proved by the following facts: an entire lack of any traces of surface volcanism; gradual transition of the rocks forming the subvolcano — without any change in mineral constitution — from the crystalline-granular quartz-diorites disclosed in the deeper parts, across the andesites of different (gradually de-

creasing) degrees of crystallization, to the andesite of vitrous basic material (traceable in a vertical extension of 1000 m) discovered immediately under the crystalline slate cover; the presence of the crystalline slate remnants of the one-time cover of the massif at several places, accompanied by contact breccias.

The pneumatolitic effects accompanying the magmatic intrusion produced turmalinization along the contact of the andesite with the crystalline slate. The hydrothermal phenomena resulted in sulphidic ore-veins traversing the subvolcano. Along the veins, similarly under hydrothermal effects, a vigorous transformation (propilitization, epidote-formation, pyritization, sericitization, kaolinization, silification) of the rock can be observed.

As for the age of the andesite mass, some information may be obtained merely by the andesite dykes and bed veins situated farther off from the main mass.

К ПЕТРОГРАФИИ СУБВУЛКАНИЧЕСКОГО МАССИВА В РАЙОНЕ ТОРОЯГИ

А. СЁКЕ

Р е з ю м е

Субвулкан в районе с. Торояга (Боршабанья), представляющий крайнюю южную часть Марамарошского нагорья, органически сочленяется к третичной вулканической цепи, выдержанно протягивающейся внутри дуги Восточных Карпат.

Окрестность рассматриваемого массива сложена эпизонально измененными кристаллическими сланцами (серицитовые и хлоритовые сланцы, порфироиды, черные кварциты и т. д.), на которые налегают верхнемеловые, эоценовые и олигоценовые отложения Марамарошского бассейна. Ядро биотито-амфиболандезитового субвулкана представлено массивом неправильного очертания, вытянутым в СЗ—ЮВ-ом направлении, который в свою очередь окружается системой даек, также андезитами сложенной.

Субвулканическая природа массива полностью подтверждается следующими фактами: полным отсутствием следов какого-либо наземного вулканизма; постепенным, без изменения минералогического состава, переходом слагающих субвулкан пород от обнаженных в более глубоких частях разреза кристаллических-зернистых кварцевых диоритов, через андезиты разных стадий (постепенно уменьшающейся) кристаллизации, до андезитов со стекловатой основной массой, вскрытых под кровлей, представленной кристаллическими сланцами (что прослеживается на расстоянии 1000 м по вертикали). Останцы кристаллических сланцев бывшей кровли массива, сопровождаемые контактовыми брекчиями, были обнаружены в ряде мест.

Пневматолитовые эффекты, сопутствовавшие внедрению магмы, привели к турмалинизации на контакте между андезитами и кристаллическими сланцами. Гидротермальные процессы создали жилы сульфидных руд вкрест простирания субвулкана. Вдоль жил — также вследствие гидротермальных процессов — наблюдается интенсивное изменение породы (пропилитизация, образование эпидота, пиритизация, серицитизация, каолинизация, окремнение и т. д.).

Насчет возраста андезитового массива можно получить некоторые сведения только благодаря изучению андезитовых даек и пластовых жил, внедрившихся в эоценовые и олигоценовые отложения, залегающие далее от ядра массива.

DIE ROLLE DES HELVETISCH-TORTONISCHEN DAZITTUFFHORIZONTS IM NEOVULKANISCHEN INNERKARPATISCHEN BEREICH

Von

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Der kennzeichnendste Leithorizont im Mátra- und Cserhát-Gebirge (Nordungarn) ist ein dazitischer-andesitischer Tuffkomplex an der Helvet—Tortonischen Grenze. Der Verfasser stellt die Frage, ob es nicht zweckmäßig wäre, in der Korrelation die Untersuchung mit der Forschung dieses Leithorizontes zu beginnen.

Ein Vergleich der geochemisch-petrographischen Struktur der neovulkanischen Decke des Mátra-Gebirges mit der Konstruktion der Vulkanite des slowakischen, von diesem in Luftlinie 100 km nordöstlich gelegenen Schemnitz-Kremnitzer Erzgebirges läßt eindeutig eine große Ähnlichkeit in der zeitlichen Reihenfolge der Gesteine erkennen. In beiden Gebirgen ist gleicherweise ein allmähliches Saurerwerden der vulkanischen Produkte, dann wieder die Umkehr in das Basische zu beobachten. Bei den älteren Gliedern, gleich am Anfang der vulkanischen Tätigkeit, finden wir dennoch einen sehr wesentlichen Unterschied zwischen den beiden Gebirgen. Dies bezieht sich eben auf den kennzeichnendsten Tuffhorizont des Mátra-Gebirges und gerade auf diese Erscheinung möchte ich hier eingehen.

Die Reihenfolge der neovulkanischen Produkte des slowakischen Schemnitz-Kremnitzer Erzgebirges kennen wir aus der Bearbeitung von FIALA, die später von KUTHAN ergänzt wurde. Nach ihnen beginnt die neovulkanische Reihenfolge mit tortonischen Piroxenandesiten, die oft propilitisiert und kaolinisiert sind.

Das Liegende der neovulkanischen Decke im Mátra-Gebirge besteht aus einem in einer Mächtigkeit von 100—250 m anstehendem helvetischem, tonigemmergeligem Sandstein (»Slir«). An den oberen Horizont des helvetischen Sandsteins mischen sich schon andesitische Piroklastika, stellenweise bildet sich sogar in den oberen Schichten des Sandsteins ein selbständiger, Lapilli-enthaltender Andesittuff-Horizont aus. Diese Andesittuffstreuung führte eigentlich die helvetisch-tortonische große vulkanische Periode ein. Am oberen Teil des Komplexes nimmt das tuffige Bindematerial der Andesitlapillien einen dazitischen Charakter an. Dies weist darauf hin, daß mit geringem Zeitunterschied, ja sogar gleichzeitig zwei vulkanische Zentren gewirkt haben mochten, die unterschiedliches Material lieferten. Die Materiallieferung der andesitischen

und dazitischen vulkanischen Zentren war wechselnd. Die dieser älteren, andesitischen Tuffstreuung zugehörenden Lavaströme und Flüsse finden wir nur im westlichen und nordwestlichen Teil des Mátra-Gebirges vor. Die ältesten Piroxenandesite der Reihenfolge von FIALA-KUTHAN im Schemnitz-Kremnitzer Erzgebirge sind vielleicht mit diesen gleichaltrig.

Der kraftvolle tertiäre Vulkanismus entwickelte sich auf dem Gebiet der Mátra zu der Zeit, als die Dazittuff-Anteile im oberen Teil des zuvor beschriebenen dünnen Andesittuffkomplexes das Übergewicht erlangten. Dieser Dazittuffkomplex ist auf dem ganzen Gebiet des Gebirges, ja selbst außerhalb seines Bereiches (z. B.: Cserhát, Börzsöny, Bükk) in großer Verbreitung und Mächtigkeit bekannt. Und gerade im Fehlen dieses dazitischen, tuffischen Leithorizontes im Schemnitz-Kremnitzer Erzgebirge besteht der große Unterschied im Aufbau der beiden einander nahestehenden neovulkanischen Gebiete.

Die Mächtigkeit des besprochenen dazittuffreichen Leithorizonts beträgt in der Mátra 150—250 m. Im zentralen Teil der Mátra, in der Nähe von Galyatető wurde seine Mächtigkeit in einer vor kurzem beendeten Bohrung mit 184 m ermittelt. Die früheren Verfasser nannten diesen Komplex den »mittleren Rhyolithtuff-Horizont«. Neuere Untersuchungen in dem Dazittuffkomplex zeigen sogar eine Zumischung von mehr oder minder andesitischen Piroklastika im mittleren Teil des Gebirges fast auf jedem Horizont. Deshalb könnte dieser Komplex im mittleren Teil des Gebirges eindeutiger als »Dazit-Andesit-gemischter Tuff« bezeichnet werden. Die Menge des ausgestreuten gemischten Bruchmaterials auf den zurzeit bekannten Fundorten in der Mátra betrug — nach annähernder Berechnung — ca. 22—25 km^3. Im dazitischen Tuffkomplex sind außer Andesitlapilli stellenweise viele stark verkieselte Dazitbomben zu finden. Das Maximum der Bomben befindet sich im östlichen Abschnitt des heutigen andesitischen Hauptkammes des Gebirges. Daraus können wir die Folgerung ziehen, daß das dazitische Explosionszentrum auch auf dem östlichen Gebiet des heutigen Gebirgshauptmassivs oder südlich in dessen unmittelbarer Nachbarschaft gelegen hat.

Das Alter des helvetischen Schliers, der den Unterbau der neovulkanischen Decke des Mátra-Gebirges bildet, wurde auf faunistischer Grundlage verläßlich festgestellt. Auf dieser Grundlage halten wir die mit Andesit-Piroklastika gemischten Dazittuffe für tortonisch. Wenn es gelänge, diesen dazittuffitischen Komplex auf den unteren Horizonten der nördlich der Mátra und des Cserhát befindlichen slowakischen neovulkanischen Komplexe auszuweisen, wäre die Identifizierung der Horizonte der südslowakischen und nordungarischen andesitischen Neovulkanitdecken auf eine festere Grundlage gestellt. Dies wäre deshalb wichtig, weil hier die mit den tortonischen andesitischen Gesteinen zusammenhängende verläßliche Fauna und Flora fast gänzlich fehlt.

Mehrere Verfasser halten das Vorhandensein eines alpiden granitartigen Magmatismus im Inneren, u. zw. hauptsächlich im nördlichen Teil des neovul-

kanischen Kranzes innerhalb des Karpatenbogens für wahrscheinlich. Die horizontale Ausdehnung dieses hypothetischen tiefliegenden Massivs wäre durch die Verbindungslinien des jungen vulkanischen Kranzes der Gebirge von Schemnitz-Kremnitz und Novohrad, des Cserhát, der Mátra, Bükk sowie von Tokaj und Eperjes im Westen, Süden und Osten begrenzt. Dieses kompakte, nicht zerbrochene Massiv ist — nach VARČEK — wahrscheinlich von den jungen innerkarpatischen Vulkanen umgeben. Das mag der Grund dafür sein, daß die Orientation dieses Kranzes anders verläuft, als dies an der Grenzlinie des gefalteten Karpatenbogens in der Lage eines neogenen Vulkanismus zu erwarten wäre. (Interessant ist die mit dieser Vorstellung übereinstimmende Beobachtung, daß die Sideritbildung im Inneren des erwähnten abgegrenzten Gebietes verbreitet ist, während sich die polimetallisch subvulkanische Mineralisation im neovulkanischen Kranz ausgebildet hat.)

Ich möchte die Frage stellen, ob es nicht zweckmäßig wäre, in der Korrelation der neogenen Tuffhorizonte diesen das tatroveporid-gemerid Kristallinikum umfassenden Ring als eine getrennte Einheit für sich zu betrachten und die Untersuchung mit der Forschung dieses Leithorizonts zu beginnen. Das Beispiel der ungarischen Mátra- und Cserhát-Gebirge zeigt, daß den kennzeichnendsten Leithorizont an der helvet-tortonischen Grenze eben dieser dazitische-andesitische Tuffhorizont bildet.

THE ROLE OF THE DACITE TUFF LEVEL AT THE HELVETIAN—TORTONIAN BOUNDARY IN THE INNER CARPATHIAN VOLCANIC WREATH

By

A. VIDACS

Abstract

In the Mátra Mountains, Northeast Hungary, Neogene volcanics are underlain by 100 to 250 metres thick Helvetian clayey-marly sandstone complex ("Schlier"). The phase of intense volcanic activity in the Helvetian and Tortonian was introduced by a scattering of andesite tuff. In the upper part of this tuff the tuffaceous cement of the andesite lapilli gradually assumes a dacitic composition. At about the time the dacitic material became dominant in the upper part of the tuff that intense volcanic activity exploded in the Mátra Mountains. The dacite tuff horizon can be traced all over the Mátra Mountains and beyond (Börzsöny, Cserhát and Bükk Mountains, etc.) which is of considerable extent and thickness. In the Mátra Mountains its thickness ranges from 100 to 250 metres.

The Helvetian schlier underlying the Neogene volcanics of the Mátra Mountains has reliably been proved to be Helvetian on the strength of a wealth of fossil evidence. On this basis the dacite tuff containing also andesite pyroclastics is set at the beginning of the Tortonian.

Several authors presume the existence of a hypothetical Alpine pluton with the Neogene Inner Carpathian volcanic wreath. In the west, south and east the outlines of this magmatic mass are supposed to be marked by the crest of the Kremnitz—Štiavnické Rudohorie—Novohradské vrch — Cserhát—Mátra—Bükk—Tokaj-Eperjes range (C. VARČEK).

It is worth while to consider whether in correlating the Neogene tuff horizonts it would not be expedient to regard this ring surrounding the Tatroveporide-Gemeride mass as a separate unit and to unravel its structure by tracing this marker horizon. The Hungarian example of the Mátra and Cserhát mountains shows this dacite-andesite tuff to be the best marker for the Helvetian—Tortonian boundary.

О РОЛИ ГОРИЗОНТА ДАЦИТОВЫХ ТУФОВ ГЕЛЬВЕТСКОГО-ТОРТОНСКОГО ВОЗРАСТА ВО ВНУТРИКАРПАТСКОЙ НЕОВУЛКАНИЧЕСКОЙ ЗОНЕ

А. ВИДАЧ

Р е з ю м е

В горах Матра, северная Венгрия, неовулканический покров подстилается гельветскими глинисто-мергелистыми песчаниками («шлир») мощности 100—250 м. Крупная гельвето-тортонская вулканическая деятельность началась выбросами андезитовых туфов. В верхней части толщи туфогенный цемент андезитовых камешек (лапилли) преобрел сильно дацитовый характер. Интенсивный третичный вулканизм в районе гор Матра развился тогда, когда в верхней части маломощной толщи андезитовых туфов дацитовые туфы стали преобладать. Данная толща дацитовых туфов известна по всей территории гор Матра, и даже за пределами их (например — Черхат, Бёржёнь, Бюкк), будучи представленной выдержанной и мощной толщей.

Мощность указанного важного руководящего горизонта в горах Матра колеблется в пределах 150—250 м.

Возраст гельветского шлира, подстилающего неовулканический покров гор Матра, был фаунистически надежно определен. На этом основании смешанные с андезитовыми пирокластитами дацитовые туфы считаются уже тортонскими.

Ряд авторов считает вероятным наличие гипотетического альпийского магматизма внутри неовулканического кольца Карпат. О максимальном горизонтальном распространении этого глубинного гранитоидного массива означает линия, связывающая отдельные члены молодой вулканической зоны: Кремницко—Штиавницке Рудохорие — Новоградске Врхи — Черхат — Матра — Бюкк — земпленско-сланские горы (Ц. Варчек).

Стоит обсудить вопрос: Не было ли бы целесообразным при корреляции неогеновых туфовых горизонтов рассматривать это кольцо, окружающее татровепоридный-гёмёридный кристаллический фундамент, как самостоятельную зону, и начать соответствующие исследования для решения вопроса — прослеживанием рассматриваемого руководящего горизонта? Горы Матра и Черхат свидетельствует о том, что на границе между гельветским и тортонским ярусами наиболее характерным руководящим горизонтом является менно рассматриваемый горизонт дацито-андезитовых туфов.

DIE CHRONOLOGIE DER TERTIÄREN PYROKLASTITE UNGARNS

Von

F. HORUSITZKY

UNGARISCHE GEOLOGISCHE ANSTALT, BUDAPEST

Verfasser unterzieht die Pyroklastite Ungarns einer chronologisch-erdgeschichtlichen Betrachtung, wobei er auf den Synchronismus verweist, der zwischen den Pyroklastithorizonten des Landes zu bestehen scheint, und auch die stratigraphisch-erdgeschichtliche Bedeutung dieser Tatsache unterstreicht. Er verfolgt und parallelisiert die einzelnen Pyroklastit-Horizonte der ungarischen Mittelgebirge im Paläogen vom Obereozän durch die lattorfische und rupelische Stufe hindurch. Im Miozän bezeichnet er sodann drei große Pyroklastitgruppen als stratigraphisch unterscheidbar: die in der aquitanisch-burdigalischen Stufengrenze anstehenden »unteren Rhyolithtuffe«, die an der helvetisch-tortonischen Grenze abgelagerten »mittleren Rhyolithtuffe« mit den begleitenden Andesittuffen und die Gruppe der sarmatischen »oberen Rhyolithtuffe«. Auf Grund der Tuffhorizonte unternimmt Verfasser auch den Versuch einer erdgeschichtlichen Gliederung des tieferen Miozäns im Mecsek-Gebirge. Sodann weist er auf den Umschlag des sialischen in den simatischen Magmatismus im oberen Pliozän hin, dessen jüngste Produkte im Liegenden bei Salgótarján Wirbeltierreste des Villafranchiens enthalten. Diese Eruptionen förderten Basanite und Basanittuffe. Die Verteilung der vulkanischen Zyklen betrachtet er durchwegs vom diastrophischen Gesichtspunkt aus, wobei er die Zusammenhänge mit den orogenen Phasen hervorhebt.

Was die weitere Parallelisierung betrifft, hält Verfasser die lattorfischen Tuffe in den sogenannten »Tarder Schichten« für zwanglos parallelisierbar mit den Tuffeinlagerungen in den karpatischen Melettaschiefern. Zu der Parallelisierung unserer Pyroklastiten mit den slowakischen Pyroklastiten wäre seines Erachtens eine Vereinheitlichung der miozänstratigraphischen Nomenklatur erwünscht. Für Siebenbürgen hingegen schlägt Verfasser die Tieferverlegung der Dazittuffe von Dej und ihre Parallelisierung mit unseren »unteren Rhyolithtuffen« vor.

Eine Tabelle über die zeitliche und regionale Verbreitung der Pyroklastite Ungarns ist beigegeben.

Die Kenntnis der zeitlichen Verbreitung der vulkanischen Tätigkeit kann nicht nur auf manche spezielle Fragen der Paläovulkanologie Antwort geben, sie vermag auch breitere erdgeschichtliche Zusammenhänge zu erschließen.

Das Lebhafterwerden der vulkanischen Tätigkeit in den revolutionären Zeitabschnitten der Erdgeschichte, d. h. während der orogenen Zeiträume, und ihre verhältnismäßige Abschwächung zur Zeit der epirogenen Entwicklungsphasen kann jedenfalls als gesetzmäßig aufgefaßt werden.

Der Synchronismus der größeren vulkanischen Ereignisse versteht sich somit von selbst. Die auf große Entfernung gelangenden Pyroklastite der größeren Eruptionszyklen können daher auf diesem Gebiete mit Recht als chronologische Leithorizonte dienen.*

* Bezüglich des Synchronismus führt PANTÓ (Seite 225 dieses Bandes) eine gewissermaßen andere Ansicht vor. (Red.)

Dem kretazischen (neokomen) Trachidolerit-Phonolitvulkanismus des Mecsek-Gebirges folgte in der vulkanischen Tätigkeit auf dem Gebiet Ungarns eine längere Pause. In den oberkretazischen-untereozänen Schichtenreihen finden wir hier noch keine Spuren von vulkanischem Material. Gegen Ende des Eozäns nähern wir uns indes schon einer hochwichtigen erdgeschichtlichen Episode, während der das Westliche Ungarische Mittelgebirge die Grundzüge seiner großtektonischen Gliederung erhielt, und die der pyrenäischen Phase zugerechnet werden kann. Die »pyrenäische Phase« zerfällt hier in zwei Unterphasen. Die ältere fällt mit dem Beginn des durch eine allgemeine Transgression gekennzeichneten obereozänen Sedimentationszyklus zusammen. Sie war von der Wiedererlebung der vulkanischen Aktivität begleitet. Die vulkanischen Ausbrüche dieser Zeit sind der Transgression unzweifelhaft vorgegangen, anderseits setzten sie sich aber auch während des Bartonien-Priaboniens fort.

Im Transdanubischen Mittelgebirge stoßen wir auf den Beginn der eozänen vulkanischen Tätigkeit am Nordrande des Velenceer-Gebirges. Das kristalline Grundgebirge ist hier durch Pyroxen- und Amphibolandesiteruptionen durchgebrochen. Sie stellen wahrscheinlich die ersten tertiären Ausbrüche dar. Hierauf weist — unter anderen — eine Bohrung bei der Gemeinde Lovasberény hin, aus welcher eine Reihe andesitischer obereozäner Kristalltuffeinlagerungen gemeldet wurde.

Am Südrand der südlichsten ausgepreßten Schollen des Budaer Gebirges finden wir Reste eines polymikten obereozänen Grundkonglomerats, das bei Budaőrs Kinderkopfgröße erreichende Eruptiveinschlüsse in großer Zahl enthält. Die Einschlüsse bestehen aus einem grünlichen, dichteren Vulkanit und aus dunkelgrauem Gestein mit vesikulärer Struktur. Sie sind quarzfrei, ihre Feldspäte sind kaolinisiert oder durch Chalcedonpseudomorphosen vertreten. Die Einschlüsse der Konglomerate sind meist scharfkantig oder kaum abgewetzt, woraus man auf unweit liegende Eruptionszentren schließen kann.

Obereozäne Basalkonglomerate mit Eruptivgesteinseinschlüssen sind hier und da auch im Inneren des Gebirges auffindbar. Sie erreichen nach Koch am Südrand des Gebirges die größte Mächtigkeit. Ihre Korngröße wird gegen Norden hin allmählich feiner und gleichzeitig nimmt ihre Abrollung zu. Das Material stammt also aus dem Süden, d. h. aus der Umgebung des Velenceer Gebirges.

Koch und später Széky-Fux vermuteten, daß die ersten obereozänen Eruptionen nur quarzfreie Produkte lieferten. Mit Vigh haben wir aber festgestellt, daß Ausbrüche, die quarzfreie und quarzführende Gesteine lieferten, schon seit Anfang des oberen Eozäns nebeneinander erfolgten. Wir fanden am Hügel Ferenchalom, im Liegenden des obereozänen Nummulitenkalksteines, in Spalten des triadischen Dolomits, einen zersetzten Pyroklastit, der neben hydrothermal limonitisierten Pyritkörnchen und Chalzedon, Andesin und

große korrodierte Quarzkörner einschließt. Zerstreute Quarzdihexaeder sind auch im Hangenden, im Nummulitenkalkstein auffindbar. Der Tuff gelangte demnach vor der Transgression in die Spalten.

Der Synchronismus der vulkanischen Tätigkeit durch das obere Eozän läßt sich noch weiter verfolgen. Dünne Tuffeinlagerungen, wie in der Bohrung bei Lovasberény, wurden in gleicher stratigraphischer Lage auch im Budaer Gebirge schon längst beobachtet (Koch, Hofmann usw.). Mit Vigh habe ich im Budaer »Hűvösvölgy« (Páfrány Str.) im Bryozoenmergel eine Tuffeinlagerung festgestellt, die 2 m Mächtigkeit erreichte. Das Gestein enthält als Hauptgemengeteile Quarz und Feldspäte, von etwa labrador-bytownitischer Zusammensetzung. Spuren des obereozänen Vulkanismus sind auch aus dem Bakony und dem Gerecse-Gebirge (Zirc, Dudar, Padrag, Halimba usw.) bekannt.

Der nachfolgende Horizont, aus dem die Fachliteratur vulkanische Tuffeinlagerungen erwähnt, wäre der sog. »Budaer Mergel«. Die Angaben, die sich auf den Pyroklastitgehalt des Budaer Mergels beziehen, müssen aber revidiert werden, und ebenso ist die chronologische Lage der einschließenden Schichten umzuwerten.

Der epirogene und Sedimentationszyklus des Obereozäns endet mit einer Hebungsphase, die dem Zusammenschub der pyrenäischen Hauptphase folgte. Die postorogenen Ablagerungen der unteroligozänen lattorfischen Stufe sind in zwei Fazies entwickelt. Im Norden wirkte entweder noch die »infraoligozäne Denudation«, oder es lagerten sich die groben Sandsteine und Konglomerate des sog. »Hárshegyer Sandsteins« ab. In der Südzone unseres Mittelgebirges findet sich statt der Hárshegyer Sandsteine eine Ablagerung, deren Schichten wir nach Majzon als »Tarder Schichten« bezeichnen. Die Tarder Schichten sind dunkelgraue, gelblich-bräunlich verwitternde, fein gebänderte Gebilde von etwa »warwen«-artiger Textur, die durch die dichte Wechsellagerung von helleren und dunkleren (humosen-bitumenösen) dünnen Schichtchen entstand. Sie sind sehr feinkörnig, glimmerreich, pyrithältig und foraminiferenfrei. Häufig finden sich in ihnen Fischreste, Schuppen, und dabei prachtvoll erhaltene Blätterabdrücke. Offenbar sind sie in einem ruhigen, seichten ästuarartigen Sedimentationsraum mit schlecht belüftetem, schwefelwasserstoffhaltigem Wasser entstanden. Man darf sie nicht mit dem neritischen, foraminiferenreichen Budaer Mergel, oder mit dem rupelischen Kisceller Ton verwechseln, wie dies oft geschah.

Den »Tarder Schichten« entspricht auch jenes »Melettaschuppen« enthaltende foraminiferenfreie Sediment mit Rhyolithtuffeinlagerungen, das Szabó einst aus den Bitterwasserbrunnen von Südbuda als Kisceller Ton erwähnt, ferner das ebenfalls durch Fischschuppen gekennzeichnete und 6 Tuffschichten einschließende Sediment, welches A. Koch aus den damaligen Aufschlüssen beim Statistischen Amt auch als Kisceller Ton beschrieben hat. Hierher zu stellen ist auch jener sog. »Budaer Mergel«, aus dem von Budaer

Farkasrét (Diana Str.) mehrfache Tuffeinlagerungen erwähnt wurden. In den Aufschlüssen beim Untergrundbahnbau in Budapest stellte ich fest, daß die Tuffeinlagerungen stets an die lattorfischen »Tarder Schichten«, nicht aber an den priabonisch-bartonischen Budaer Mergel gebunden sind. Die Tuffeinlagerungen finden wir auch in den Tarder Schichten der Umgebung des Bükk-Gebirges wieder.

Die vulkanische Tätigkeit setzte sich im Mitteloligozän noch fort, wie das die wiederholten Tuffeinlagerungen im Kisceller Ton in der Umgebung von Budapest und im Bükk-Gebirge verraten. Bezüglich der Einzelheiten der Zeugen des oligozänen Vulkanismus in der Gegend des Bükk kann ich auf die Arbeit von BALOGH verweisen.

Die Meinungsunterschiede über die Chronologie des miozänen Vulkanismus sind eher nomenklaturischer Natur.

Im Miozän unterscheiden wir drei Tuffhorizonte: u. zw. die »unteren«, die »mittleren« und die »oberen« (sarmatischen) Rhyolithtuffe.

Diese Gliederung ging hauptsächlich von den Salgótarjáner und Borsoder Kohlenbecken aus. Hier begann nach dem Abschluß der chattischen Regression eine neue — und zwar mediterrane — Transgression, deren litorale und sublitorale Ablagerungen die Schichten des Oligozäns diskordant überlagern. Diesen verhältnismäßig kurzen Sedimentationszyklus beendet bald wieder eine Erhebung, die durch kontinentale Ablagerungen von Schottern, Konglomeraten, bunten Tonen angedeutet ist. Diesen kontinentalen Schichten überlagerte der sog. »untere Rhyolithtuff«, in Liegenden der »kohlenführenden Schichtengruppe«, die wieder einen neuen Sedimentationszyklus einleitet. Den dem Chattien folgenden ersten mediterranen Sedimentationszyklus fasse ich — im Sinne der ursprünglichen Definition der Stufennamen — als den Zyklus der aquitanischen Stufe auf, während einige meiner ungarischen und tschechoslowakischen Fachkollegen diese ersten mediterranen Ablagerungen schon als Burdigalien betrachten.

Die Folge dieses Meinungsunterschiedes ist, daß während meiner Meinung nach die unteren Rhyolithtuffe, als leitende Grenzbildungen, zwischen dem Aquitanien und Burdigalien liegen, nach anderen Meinungen sie zwischen die burdigalische und helvetische Stufen zu stellen sind. Ich fasse den unteren Rhyolithtuff als synorogene Bildung der sawischen orogenen Phase auf. Da möchte ich auf den Umstand aufmerksam machen, daß STILLE die sawische Phase bekanntlich eben zwischen die aquitanischen und burdigalischen Stufen stellte. Auf Grund eines annehmbaren und wenigstens annähernden Synchronismus der Pyroklastitstreuungen fügen wir die oberen kontinentalen Schichtglieder des Miozäns vom Mecsekgebirge in unsere chronologische Tafel ein. Der hier vorkommende tiefermiozäne Rhyolithtuff liegt über groben terrestrischen Konglomeraten und unter einer mächtigen kontinentalen-fluviatilen Schichtenreihe. Die grobdetritischen basalen Bildungen müssen also die aquitanische

Die chronologische Verbreitung der vulkanischen Produkte in Ungarn. Zusammengestellt von: F. HORUSITZKY

		Epirogene Zyklen und chronologische Einreihung	Orogene Phasen	Mecsek-Gebirge	Velenceer Gebirge	Budaer Gebirge	Bakonyer Gebirge	Börzsöny-Gebirge	Dunazug-Gebirge	Cserhát-Gebirge und linksufriges Hügelgebirge bei Budapest	Mátra-Gebirge	Bükk-Gebirge, Gegend von Nógrád und des Sajó-Tales	Tokajer Gebirge
Quartär		Grenze von Pliozän und Pleistozän	Romanische Phase				Basanite und deren Tuffe					Basanite und deren Tuffe	
Pliozän													
Oberes	Miozän	Sarmatien				Bentonitisierte Rhyolithtuffe im sarmatischen Kalk (Tétény usw.)			Sarmatische Tuffe (Szentendre)	Einlagerungen von bentonitischem Rhyolithtuff im sarmatischen Kalk	Rhyolithtuff am Rande der Mátra im oberen Sarmatikum. Rhyolithtuffeinlagerungen enthaltender Biotitandesit	»Oberer« Rhyolithtuff	Rhyolithtuff, Rhyolith, Kalitrachyt, Hypersthenaugitandesit
Mittleres		Helvetien—Tortonien-Grenze	Steirische Phase	Oberer Tuff an der Grenze Helvetien—Tortonien		Rhyolithtuff an der Grenze Tortonien—Helvetien (Budafok)	Bentonite im Tortonien (Bánd, Szentgál)	Andesite und ihre Tuffe an der Grenze von Helvetien—Tortonien und an der Basis des Tortonien	Verschiedene Andesite an der Grenze Helvetien—Tortonien und im Tortonien selbst	Pyroxenandesite, Andesittuffe und Agglomerate von Eruptionen am Eingang d. Tort. Mittl. Tuff. a. d. Grenze Helv.—Tort.	Pyroxenandesite, Tuffe, Agglomerate, Dazittuffe, mittlerer Rhyolithtuff	Südliches Deckgebirge (Tibolddaróc, Kács, Sály) usw. — Übergänge zwischen Dazit und Andesit. Dünner Pyroxenandesittuff aus der S-Seite des Bükk-Gebirges. Hangendtuff der Braunkohlenformation im Borsoder Kohlenrevier. Rhyolith-Dazit-Tuffe	Rhyolithtuff Andesit und Andesittuff
Unteres		Aquitanien—Burdigalien Grenze	Savische Phase	Dazittuff über miozänem Basiskonglomerat							Unterer Rhyolithtuff		
Mittleres—Oberes	Oligozän	Stampischer Zyklus				Rhyolithtuff-Schnüre im Kisceller Ton			Ältere Andesite (?)	Dazit des Festungsberges von Nógrád		Rhyolithtuffschnüre im mitteloligozänem Ton (Bükkszék usw.), Bentonit von Istenmező	
Unteres		Lattorfischer Zyklus	Pyrenäische Hauptphase			Tuffeinlagerungen im unteren Oligozän in der sog. »Tarder« Fazies (Budaőrs, Budapest)						Tuffeinschaltungen im unteren Oligozän (in der Fazies von Tard)	
Ober-Eozän		Barton—Priabonischer Zyklus	Pyrenäische Vorphase		Einlagerungen von Andesit-Kristalltuff im oberen Eozän (Lovasberény) Pyroxenandesit und Amphibolandesit am Ostrande des Gebirges	Einlagerungen von feinkörnigem Tuff in Kalkstein und Mergel des oberen Eozäns Einschlüsse von propylitisiertem und miarolitischem Andesit im Basiskonglomerat des oberen Eozäns	Einschaltungen von Tuffitschichten und Amphibolandesittuff im Ton und Mergelton des Bartonien (Padrag, Halimba)				Detritäre Schichten von Amphibolandesit in Kalkstein und Sandstein (Recsk, Derecske)		

Stufe, die den eruptiven Grenzhorizont überlagernden kontinentalen-fluviatilen Schichten hingegen die burdigalische Stufe vertreten.

Im Typusprofil der Umgebung der nordöstlichen ungarischen Mittelgebirge folgen auf den unteren Rhyolithtuff die Bildungen der kohlenführenden Gruppe, dann die Cardium-Corbula Schichten, die sog. Chlamysschichten, und endlich der Schlier, einen einheitlichen burdigal-helvetischen Sedimentationszyklus bildend, der eines neuen Stufennamens würdig wäre. Die ersten Spuren der neubelebten vulkanischen Tätigkeit erscheinen im obersten Teil des Schliers, in dessen Hangenden, an der Helvet-Tortongrenze — diastrophisch der »steirischen Phase« entsprechend — die »mittleren Rhyolithtuffe« in beträchtlicher Mächtigkeit auftreten.

Der »mittlere Rhyolithtuff« ist auch bei Budapest recht gut vertreten. Der Rhyolithtuff ist bei Fót und Mogyoród von Pyroxenandesitagglomeraten begleitet.

In der Hauptsache waren es die Eruptionen der Helvet-Tortongrenze und des Untertortons, die die ungarischen vulkanischen Gebirge erzeugten und eine Reihe von sauren und verschiedenen andesitischen Produkten förderten (Börzsöny, Szentendre—Visegráder, Cserhát, Mátra, Tokajer Gebirge).

Im Mátra-Gebirge entsprechen die Ausbrüche nach Szádeczky-Kardoss, Kubovics und Vidacs drei Eruptionszyklen. Im Bohrprofil von Galyatetô finden sich die ersten dazitisch-andesitischen vulkanischen Lockermaterialeinlagerungen schon im oberen Teil des Schliers. Zwischen 295 m und 475,8 m steht Dazittuff mit wechselnden Mengen von Andesittuffbeimischungen an. Diese Tuffe können den mittleren Rhyolithtuffen entsprechen, denen dann eine Stratoreihe von Pyroxen-Hypersten-Andesiten und ihre Tuffe und Agglomerate folgen (Untertorton). Die vulkanische Tätigkeit klang im Oberen Torton nur allmählich ab, was die Tuffeinlagerungen des Leithakalkes im Mátra-Gebirge und z. B. bei Sopron beweisen. Die teils vielleicht umgelagerten lapillihführenden Rhyolithtuffeinlagerungen sind auch im Rákoser Eisenbahneinschnitt bei Budapest gut aufgeschlossen.

Zu den tortonischen Pyroklastiten gehören ferner die Bentonite des Bakony-Gebirges (Bánd, Herend), die Tuffeinlagerungen in den schieferigen Tonen im Hangenden der tortonischen Lignite von Várpalota und die bentonitischen Tuffe bei Sopron.

Im Mecsek-Gebirge können wir neben die »mittleren Rhyolithtuffe« Nordostungarns die höheren »Dazittuffe« stellen, die die Ablagerungen der burdigal-helvetischen und tortonischen Schichtenreihen trennen.

In den Rahmen der »oberen Rhyolithtuffe« fassen wir die sarmatischen Rhyolithtuffe zusammen. Diese Tuffe spielen in Ungarn eine große Rolle und können eine beträchtliche Mächtigkeit (nach Pantó etwa 350 m) erreichen.

Am Rande des Mátra-Gebirges finden sich Tuffeinlagerungen im kontinentalen Untersarmat. In diese Gruppe der oberen Rhyolithtuffe gehören auch

die Bentoniteinlagerungen der Cerithienkalke südlich vom Budaer Gebirge, in den sarmatischen Kalksteinen des Tétényer Plateaus und von Budapest (Kőbánya).

Wir müssen noch erwähnen, daß ungemein mächtige miozäne Rhyolithtuffmassen in der Nordostecke der Ungarischen Tiefebene (Nyírség) durch Tiefbohrungen aufgeschlossen wurden. Diese Tuffe können mangels Meeressediments bzw. Fossilienmaterials chronologisch noch nicht näher beurteilt werden.

Damit schließen die sialischen Eruptionen des Tertiärs in Ungarn ab. Während der letzten Wiederbelebung der vulkanischen Aktivität im oberen Pliocän, die die »romanische Phase« einführt und begleitet, schlägt unser Vulkanismus in den simatischen um. Diese Eruptionen förderten in der Umgebung des Balaton und im Nordosten bei Salgótarján Basanite und Basanittuffe. Bei Ajnácskő lieferten die unmittelbaren Liegendschichten einiger Tuffe Wirbeltierreste des Villanfranchien.

Zur weiteren Korrelation der ungarischen Pyroklastite möchte ich bemerken, daß unsere unteroligozänen Tuffe mit den Tuffeinlagerungen der karpatischen Melettaschiefer zwanglos parallelisierbar sind. Die südslowakischen und die ungarischen Pyroklastite sind chronologisch gleich zu beurteilen, und ihre Korrelation läßt sich leicht durchführen, wenn wir unsere stratigraphischen Nomenklaturen in Einklang bringen. In Transsylvanien, im Liegenden der »Dazittuffe von Dej« wurden die sog. »Koroder Schichten« von TH. FUCHS als typische Bildungen des ostmediterranen Aquitaniens bezeichnet. Auf Grund dieser Erwägungen können die »Tuffe von Dej« stratigraphisch tiefer eingereiht und mit unseren »unteren Rhyolithtuffen« korreliert werden.

Als Übersicht über die zeitliche und regionale Verbreitung der vulkanischen Produkte in Ungarn möge die beiliegende Tabelle dienen.

THE CHRONOLOGY OF THE TERTIARY PYROCLASTITES OF HUNGARY

By

F. HORUSITZKY

Abstract

The pyroclastites of Hungary are examined by the author from the point of view of chronology-geological history. He refers to the synchronism apparently existing between the individual pyroclastite-stages of Hungary and points out its stratigraphical-geological-historical significance. He follows the individual pyroclastite-stages in our central mountains in the Paleogene beginning from the Upper Eocene, across the Lattorfian and Rupelian stages, establishing their parallelism. In the Miocene, then, he considers stratigraphically separable three great groups of pyroclastites: the "lower rhyolite-tuff" situated on the Aquitanian-Burdigalian boundary, the "middle rhyolite-tuff" and accompanying andesite-tuffs accumulated on the Helvetian—Tortonian boundary, finally the Sarmatian "upper rhyolite-tuff group". He attempts, according to the tuff horizons, a historical division of the deeper Miocene of the Mecsek, too. Next, he refers to the turning over of the sialic magmatism into the simatic magmatism during the Upper Pliocene, the youngest members of which, around Salgótarján, contain a Villanfranchian vertebrate fauna in their subjacent layers. These eruptions produced

basanites and basanite-tuffs. The distribution of volcanic stages are regarded by the author always from a diastrophic view, emphasizing the relations with the orogenic phases.

As to further parallelism, the author regards without any difficulty the Lattorfian tuffs in the "Tard schists" to be parallel with the tuff interbeddings of the Carpathian "Melettashales"; from the point of view of its parallelism with the Slovakian pyroclastites, he thinks the harmonization of our Miocene stratigraphy desirable; in Transsylvania, on the other hand, he suggests a deeper placing of the Dej tuff and its parallelisation with our "lower rhyolit-tuffs".

The review is accompanied by a table showing the chronological and regional distribution of the pyroclastites of Hungary.

ХРОНОЛОГИЯ ТРЕТИЧНЫХ ПИРОКЛАСТИТОВ В ВЕНГРИИ

Ф. ХОРУШИЦКИ

Р е з ю м е

Автором рассматриваются пирокласты Венгрии с хронологической-исторической позиции. Он ссылается на синхронность, существующую между отдельными горизонтами пирокластитов и указывает на его стратиграфическое-историческое значение. Горизонты пирокластитов в нашем среднегорье прослеживаются автором в палеогене, начиная с верхнего эоцена, через латторфский и рупельский ярусы и производится их сравнение. По мнению автора, в миоцене можно определить три большие стратиграфические единицы пирокластитов: «нижние риолитовые туфы», залегающие на границе аквитанского и бурдигалского ярусов, «средние риолитовые туфы» на границе гельветского и тортонского ярусов, сопровождаемые андезитовыми туфами, и «верхние риолитовые туфы» сарматского яруса. На основе туфовых горизонтов автор сделает попытку классификации глубокозалегающих миоценовых отложений в горе Мечек. Затем указывает на переход сиалического магматизма в симатический магматизм в верхнем плиоцене, наиболее поздние образования которого в лежачем боке содержат фауну Villafranchien. В результате этого извержения образовались базаниты и базанитовые туфы. Разделение вулканических участков автором рассматривается с точки зрения диастрофизма и подчеркивается взаимосвязь с орогенными фазами.

Что касается сравнения латторфских туфов в т. н. «тардском горизонте» с туфовыми прослойками в «мелеттовых сланцах» Карпат, то это автор считает вполне возможным. Относительно сравнения пирокластитов в Венгрии с пирокластитами Словакии, автор считает нужным уточнение нашей номенклатуры по стратиграфии миоцена. Кроме того автор предлагает дешские туфы (Деж) приурочить к более глубоким горизонтам аквитанского яруса.

К своей работе автор прилагает таблицу, в которой указаны региональное и хронологическое распространение пирокластитов в Венгрии.

АБСОЛЮТНЫЙ ВОЗРАСТ НЕКОТОРЫХ ГЕОЛОГИЧЕСКИХ ОБРАЗОВАНИЙ ВЕНГРИИ

Л. Н. ОВЧИННИКОВ, М. В. ПАНОВА,
Ф. Л. ШАНГАРЕЕВ

ГОРНО-ГЕОЛОГИЧЕСКИЙ ИНСТИТУТ, СВЕРДЛОВСК, СССР

В горно-геологическом институте Уральского филиала АН СССР авторы настоящей статьи выполнили определение абсолютного возраста нескольких проб интрузивных, эффузивных и осадочных пород Венгрии методом К—Ar.

Определение абсолютного геологического возраста было произведено по мономинеральным фракциям слюды и калиевого полевого шпата пород или непосредственно по однородным образцам соответствующих горных пород. Опыт показал, что наиболее точные результаты получаются при определении абсолютного возраста по биотиту (или глаукониту в осадочных породах).

По результатам исследований гранитные массивы гор Мечек и Веленце древнее перми и относятся к варисским образованиям. Возраст мечекских гранитов — 335 миллионов лет (средний карбон). Прорывающие мечекские граниты трахидолериты датируются в 110 миллионов лет (мел). Биотитоальбитовые сланцы, вмещающие граниты, насчитывают 260 миллионов лет. Однако, эта величина отражает только возраст последнего метаморфизма.

Граниты гор Веленце имеют возраст 360 миллионов лет, так что они по возрасту ближе к гранитам Эйбенштока в Саксонии, чем к мечекским гранитам. Кажется вероятным, что они формировались в промежуток времени между визейским и намюрским ярусами.

Прорывающие граниты амфиболовые андезиты насчитывают 39 миллионов лет и таким образом относятся к верхнему эоцену.

Возраст карбонатных марганцевых руд месторождения Уркут, по данным определения по глаукониту, составляет 168±9 миллионов лет (нижняя юра).

Был определен также возраст некоторых неогеновых вулканитов.

Фонолитам гор Мечек 61 ± 8 миллионов лет (нижний мел). Риолитовые туфы из месторождения Эгерь и риолиты из месторождения Дьёндёшшоймош относятся к нижнему миоцену, а калиевые трахиты из с. Телькибанья к сармату (15—24 миллионов лет).

В статье приводятся некоторые результаты определения абсолютного возраста изверженных и осадочных образований Венгрии. В сборе материала для определений оказали большую помощь академик Э. Садецки-Кардошш, доктор Панто Габор, а также В. Секи-Фукс, М. Фёльдвари-Фогл, Сабо Мартон, Чех Нэмет Иожеф, Хамор Гейза. Всем этим лицам авторы приносят глубокую благодарность.

Определения абсолютного возраста произведены в лаборатории Минералогии и геохимии Горно-геологического института Уральского филиала Академии наук СССР в г. Свердловске (Урал) калий-аргоновым методом. Как известно, калий-аргоновый метод определения абсолютного возраста минералов основан на использовании К — радиоактивности K^{40}, приводя-

щей к образованию A^{40}. Этот метод требует определения содержания калия и аргона в испытуемой пробе, а также знания констант обеих ветвей распада K^{40}: К-захвата и β-распада.

Вычисления возраста производились по формуле

$$\frac{m\,A^{40}}{m\,K^{40}} = \frac{\lambda_k}{\lambda_k+\lambda_\beta}\left[e^{(\lambda_k+\lambda_\beta)t}-1\right].$$

Для расчета возраста использовались следующие значения констант: λ_K — $5{,}57\cdot10^{-11}$ лет$^{-1}$, λ_β — $4{,}72\cdot10^{-10}$ лет$^{-1}$. Содержание K^{40} в смеси изотопов калия принято равным 1,22. 10^{-4} весовых %.

Общее содержание калия определялось дипикриламинатным и хлорплатинатным методами всегда из параллельных навесок. Извлечение аргона из пробы и его определение велось объемным методом на специальной установке, созданной на основе прибора конструкции В. Г. Хлопина и Э. К. Герлинга [2]. Определение возможного загрязнения выделяемого радиогенного аргона 40 воздушным аргоном производилось масс-спектрометром МС—2М.

Для определения возраста горных пород Венгрии были использованы мономинеральные фракции слюд, калиевого полевого шпата, а также валовые пробы породы в целом. Данные, полученные по этим минералам и по породе в целом, неравноценны. Как показывает весь мировой опыт наибольшей сохранностью радиогенного аргона обладают слюды, их анализ дает наиболее приближающиеся к истине результаты. Калиевый полевой шпат менее способен сохранять образующийся при распаде калия аргон и в большинстве случаев показывает меньшие значения возраста. Для уральских горных пород, например, абсолютный возраст по калиевому полевому шпату как правило менее абсолютного возраста, полученного по сл юде, на 15% [6]. В литературе указываются еще большие расхождения [4].

Таким образом, наиболее желательным, если не единственным, материалом для определения абсолютного возраста калий-аргоновым методом должна быть слюда. При определении возраста по калиевому полевому шпату, или же по породе в целом всегда имеется опасность получить заниженные значения. Однако, слюда имеет значительно более ограниченное распространение и мы вынуждены прибегать, особенно при определении абсолютного возраста эффузивов, к пробам породы в целом.

Хорошим материалом для определения абсолютного возраста может, вероятно, служить также глауконит, который имеет одинаковое строение со слюдой. Это показывают и определения по глаукониту Уркута. Однако, свойства глауконита с точки зрения пригодности для точного определения

абсолютного возраста, его способность к сохранению радиогенного аргона в различных условиях изучены еще недостаточно и он пока не может ставиться наряду со слюдой.

После такого предупреждающего вступления перейдем к изложению и интерпретации полученных результатов, сведенных в таблице 1.

Древнейшими интрузивными массивами на территории Венгрии являются граниты гор Мечек и Веленце. Их возраст считается несомненно старше перми и они относятся к варисским образованиям [1]. Полученные результаты определения абсолютного возраста подтверждают существующие взгляды. Гранит гор Мечек (все образцы взяты при любезном содействии геолога Хамора Гейзы) по биотиту имеет возраст равный 335 млн лет, а по полевому шпату и валовой пробе мелкозернистой разности — 280—285 млн лет. Более соответствует истине, вероятно, первая цифра: 325 млн лет. Калиевый полевой шпат крупных порфировидных выделений и мелкозернистый гранит в целом, в котором калий преимущественно сосредоточен в полевом шпате, утеряли аргон, причем эта потеря составляет около 16% — цифру, близкую к потерям в уральских полевых шпатах.

Возраст гранитов, окружающих горы Мечек, близок к варисским гранитам Урала, крупные массивы которых широко распространены на всем протяжении его восточного склона. Образование последних относится к послевизейскому времени, а абсолютный возраст по слюде по многочисленным определениям равен 315 ± 10 млн лет. Близкий возраст по данным А. И. Тугаринова имеет Эйбенштокский гранитный массив в Саксонии, прорывающий отложения нижнего карбона и метаморфизующий образования среднего карбона. Значения возраста этого гранита таковы: по биотиту 345 ± 15 млн лет, по циркону по данным свинцового метода: 325—330 млн лет.

Из обнажения возле железнодорожной станции Кишморадь, невдалеко от гранитного карьера был взят трахидолерит, по всей видимости секущий гранит массива Мечек. Это жильный трахидолерит не обнаруживает под микроскопом калиевых минералов, но содержит 4,46% калия. Его возраст оказался равным 110 млн лет, что соответствует меловому периоду. В другой части этого обнажения, представляющего собой скалистый обрыв, наблюдается сильно рассланцованная порода (сланец), под микроскопом существенно состоящая из альбита и биотита.

Абсолютный возраст этого сланца равен 260 млн лет, т. е. близок к возрасту гранита массива Мечек. Возможно он является продуктом воздействия этой интрузии на вмещающие породы кровли, так как полученные значения показывают возраст метаморфизма, а не время образования исходной породы.

В районе гор Мечек вблизи Комло конгломераты гельвета местами переполнены крупными гальками кварцевого порфира, коренные обна-

Таблица 1

Результаты определения абсолютного возраста горных пород Венгрии

№№ пп	Наименование проб и место их взятия	$\frac{A^{40}}{K^{40}}$	Возраст в млн лет	Установленный или предполагаемый геологический возраст
	А. Гранитный массив гор Мечек			
	(Карьер у ж. д. станции Кишморадь)			
1	Биотит из крупнозернистого розового гранита	0,0207	335	
2	Калиевый полевой шпат из порфировидных выделений в крупнозернистом граните	0,0169	280	
3	Мелкозернистый розовый гранит	0,0172	285±10	Каменноугольный [1]
4	Жильный трахидолерит, секущий гранит массива Мечек	0,0064	110	
5	Альбито-биотитовый сланец, вмещающий (?) гранит массива Мечек		260±7	
6	Кварцевый порфир из гальки конгломерата гельвета. Обнажение на дороге Печ—Комло перед развилкой на Манфа	0,0156	260±10	
	Б. Гранитный массив гор Веленце			
7	Биотит из крупнозернистого порфировидного гранита (образец из коллекции Геологического института)	0,0223	360	
8	Калиевый полевой шпат из крупнозернистого гранита (тот же образец из коллекции Геологического института)	0,0168	280	Каменноугольный Внедрение между визейским и намюрским ярусами [5]
9	Березитизированный крупнозернистый гранит. Карьер в юго-восточной части массива	0,0102	175±8	
10	Жильный амфиболандезит, прорывающий березитизированный гранит. Карьер в юго-восточной части массива	0,0024	38±0,5	Верхний эоцен [5]
	В. Марганцевое месторождение Уркут			
11	Глауконит из карбонатных руд	0,0099	168±9	Верхний лейас [3]
12	Глауконит из окисленных руд	0,0093	160±5	

№№ пп	Наименование проб и место их взятия	$\frac{A^{40}}{K^{40}}$	Возраст в млн лет	Установленный или предполагаемый геологический возраст
	Г. Вулканогенные породы из разных районов страны			
13	Фонолит из района гор Мечек (образец передан В. Секи-Фукс)	0,0035	61±8	Нижний мел [7]
14	Трахидолерит. Карьер возле Карас между Комло и Боньхадом	0,0018	31±4	мел
15	Туф риолита. Обнажение к югу от г. Эгер возле шоссе Будапешт—Эгер	0,0012	20±5	миоцен
16	Калиевый трахит. Штольня в Телькибанья	0,0014	24±12	миоцен (сармат)
17	Риолит. Карьер возле Дёньдёшшоймош	0,0008	15±3	миоцен

жения которого в пределах страны не найдены. Вместе с кварцевым порфиром в этих конгломератах находятся также гальки известняков и песчаников триасового возраста. Определение абсолютного возраста этого кварцевого порфира, совершенно не содержащего слюды и несколько выветрелого, давшее цифру 260 млн лет, указывает на возрастную и, вероятно также и генетическую связь его с интрузивными излияниями гор Мечек.

Несколько определений абсолютного возраста было сделано для гранитов гор Веленце. Биотит из крупнозернистой порфировидной разности (образец из музея Геологического института передан Панто) обнаружил возраст, равный 360 млн лет, несколько больший возраста биотита из гранита гор Мечек, но также близкий к возрасту биотита Эйбенштокского массива в Саксонии. Возраст калиевого полевого шпата из этого же образца оказался равным 280 млн лет, то есть таким же как возраст полевого шпата из гранита гор Мечек.

Как известно, биотит из гранита гор Веленце был использован М. Фёльдвари-Фогл для определения абсолютного возраста рубидиево-стронциевым методом. Неоднократные определения показали удовлетворительную сходимость при среднем значении 217±40 млн лет. Таким образом, наблюдается некоторое расхождение в определении абсолютного возраста гранитов гор Веленце этими двумя методами. Нам представляется, что наши цифры более правильно характеризуют возраст интрузии Веленце: они более соответствуют времени её внедрения между визейским и намюрским веками, установленному Б. Янчки [5] на основании геологических фактов и соображений. Но, свою правоту нам доказать весьма трудно, так как мы располагали, к сожалению, ограниченным материалом и повторные определения нам сде-

лать не удалось. Полученные данные совершенно необходимо проверить в дальнейшем.

Методически интересным явилось определение возраста сильно березитизированного гранита, взятого из карьера в юго-восточной части гор Веленце. Этот гранит обнаружил возраст в 175 млн лет, что является безусловно сильно заниженным и свидетельствует о нарушении радиоактивного равновесия между калием 40 и аргоном 40 при березитизации. Вряд-ли этот процесс мог происходить в мезозойское (юрское) время.

Амфиболандезит, в виде дайки отчетливо секущий в том же карьере вышеописанный березитизированный гранит, по валовой пробе имеет возраст равный 39 млн лет, что по абсолютной геохронологической шкале соответствует верхнему эоцену. Этот возраст близок к возрасту биотита верхнеэоценовых пегматитов в Вакис-Джвари в Грузии, который по данным М. М. Рубинштейна определяется в 40 ± 5 млн лет и, который служит опорной точкой для верхнего эоцена шкалы абсолютного геологического времени. По данным Б. Янчки [5] амфиболандезиты гор Веленце также имеют верхне-эоценовый возраст.

От геолога Чех Немет Иожефа были получены образцы хорошо сохранившегося глауконита из карбонатных и окисных руд марганцевого месторождения Уркут. Абсолютный возраст глауконита из первичных карбонатных руд равен 168 ± 9 млн лет, что хорошо совпадает с геологическими данными. Карбонатные руды Уркута относятся к верхнему лейасу (нижняя юра) [3] и возраст глауконита из них может быть использован в качестве опорного репера для составления абсолютной геохронологической шкалы.

Образование окисленых руд происходило в период где то от верхнего лейаса до среднего мела. Глауконит в этих рудах является первичным, не переотложенным, так как его возраст почти такой же как возраст глауконита карбонатных первичных руд. Правда наблюдается уменьшение значения возраста глауконита из окисленных руд на 5—8 млн лет, но это уменьшение в пределах ошибки метода.

Было произведено также несколько определений абсолютного возраста молодых вулканогенных образований страны по породе в целом. Точность этих определений из-за отсутствия слюды, небольшого возраста и иногда небольших содержаний калия меньшая по сравнению с предыдущими данными, хотя и определения этих пород производились по нескольку раз (от двух до пяти параллельных анализов).

Фонолит из района гор Мечек, переданный нам В. Секи-Фукс, показал абсолютный возраст, равный 61 ± 8 млн лет. Насколько нам известно, этот фонолит по геологическим данным образовался в нижнем мелу [7] и полученная цифра возраста, таким образом, вероятно является заниженный вследствии потери аргона.

Также меловой возраст по свидетельству Хамора Гейзы, имеет трахидолерит, разрабатывающийся возле с. Карас между Комло и Боньхадом. Его абсолютный возраст по нескольким определениям оказался равным всего 31 ± 4 млн лет. Причина такого большого расхождения с геологическими данными в этом случае не ясна. Возраст миоценовых пород: туфа риолита из обнажения близ г. Эгер, риолита из Дёньдёшшоймоша и калиевого трахита из Тэлькибаньи определен в 15—24 млн лет. Это хорошо соответствует геологическим данным. Только калиевый трахит из Тэлькибаньи, относимый к сармату, при значительных колебаниях показывает абсолютный возраст, более отвечающий низам миоцена.

Несмотря на небольшое число определений и разную степень их достоверности, изложенные в статье первые результаты определения абсолютного возраста калий-аргоновым методом убедительно показывают достаточную надежность метода и возможность его широкого применения для решения разнообразных вопросов геологии Венгрии. Надо пожелать чтобы начатые в стране работы по постановке этого метода в самом скорейшем времени увенчались успехом.

ЛИТЕРАТУРА

1. Садецки-Кардошш, Э.: О магматическом механизме Карпатского срединного массива. Материалы Геохимической конференции Академии наук Венгрии. Будапешт, 5—10, октября 1959. Рукопись. — 2. Хлопин, В. Г. и Герлинг, Э. К.: Сборник «Природные газы» вып. 4—5, 1932. — 3. Drubina-Szabó, M.: Manganese Deposits of Hungary. Econ. Geol., N 6, vol. 54, 1959. — 4. Goldich, S. S.—Baadsgaard, H. and Nier, A. O.: Investigations in — A^{40}/K^{40} dating. Trans. Amer. Geophys. Union, **38,** 4, 1957. — 5. Jantsky, B.: Velencei hegység földtana. Budapest, 1957. — 6. Ovchinnikov, L. N., Harris, M. A.: Absolute age of geological formations of the Urals and the Pre-Urals. **XXI,** IGC, 1960. — 7. Széky-Fux, V.: Die Rolle der magmatischen Gesteine im Steinkohlenkomplex von Komló. Acta Geologica Ac. Sci. Hung. **I,** 1, 1952.

ABSOLUTE AGE OF SOME GEOLOGICAL FORMATIONS OF HUNGARY

By

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Abstract

The authors have determined in the Mining-Geological Institute of Uralian department of the Academy of Sciences USSR the K—Ar dating of some intrusive, effusive and sedimentary rocks from Hungary.

The absolute age determinations were carried out on the mica or felspar concentrate of the sample or on the homogenized sample itself. Experience has shown the determinations with biotite (on glauconite in the case of sedimentary rocks) are the most reliable.

The study reveals the intrusive granite massifs of the Mecsek and Velence Mountains to be older than Permian and to belong to the Variscan structural unit. The granite of the Mecsek Mountains is 325 million years old (lower to middle Carboniferous). The trachydolerite traversing this granite is 110 million years old (Cretaceous). The biotitic albite schist constitut-

ing the country rock for the granite yielded a figure of 260 million years: this, however, is only the period of the metamorphism.

The granite of the Velence Mountains is 360 million years old. This value is nearer to that of the Eibenstock granite in Saxony than it is to that of the granites of the Mecsek Mountains. It was formed in all probability between the Visean and Namurian stages of the Carboniferous.

The intrusions of amphibolandesite treversing the granite of the Velence Mountains are 39 million years old (upper Eocene).

Determinations on the glauconite contained in the sediment reveal that the carbonatic manganese ore of the Urkut deposit is 168 $\pm$ 9 million years old (lower Jurassic).

Also the ages of some Neogene volcanics have been determined.

The phonolite of the Mecsek Mountains is 61 $\pm$ 8 million years in age (lower Cretaceous). The rhyolite tuff of Eger and the rhyolite of Gyöngyössolymos belongs to lower Miocene whereas the potash trachyte of Telkibánya is Sarmatian in age (15 to 24 million years age).

ON THE PRESENT STAGE OF DEVELOPMENT OF THE POTENTIAL CONCEPT IN GEOCHEMISTRY

By

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The geochemical potential concept gives the possibility to interpret the geochemical processes in a uniform way, beginning with the formation of the mobile gaseous or liquid state to the non, or slightly mobile solid compounds, even if no thermochemical data are available. In this concept merely atomic constants are used in the form of cationic, anionic, complex anionic and compound potentials. Compound potential is essentially the arithmetic mean of the cations and anions of the compound. It also allows to take into consideration the coordination number of the compound (Table 2), i.e. the different modifications of the same compound (Table 3 and 4), further the ionic or covalent type of bond (Table 6).

In the most cases, it is also possible to derive from the compound potential, the relative tensions of fusions and solubilities. By the compound potential it is possible to establish theoretically the probable course of crystallization in the igneous rocks under varying environment as well as in the sediments. The actual course of crystallization may be, however, modified by other factors, such as the concentration and nature of the ions present in the magma its viscosity, etc.

Introduction

One of the aims of geochemistry is to study the connections observed among the natural processes of rock and ore forming and to interpret the regularities of the relations between these processes. Geochemistry endeavours to study the migration of the elements in the gaseous state as well as in aqueous solutions and in melts, respectively. It examines the mobility of the elements, the conditions and circumstances of their crystallization as well as the stability relations of their solid compounds. The fields of stability and mobility are essentially determined by the fusion temperatures and solubility relations of the solid compounds. The boundary surface between these two fields, i.e., the surface of crystallization is, however, not constant, but variable in function of temperature, pressure and concentration. The quantitative interpretation of these relations can be given principally on the basis of thermodynamics. However, either the necessary thermochemical data are lacking in many cases or the temperature and pressure relations playing an essential role in the process are not exactly known.

The geochemical potential concept introduced by Szádeczky-Kardoss (1954) gives the possibility to interpret geochemical processes even, if no ther-

mochemical data are available; the ionic, atomic and compound potentials can be calculated from atomic constants.

1. The concept and significance of the compound potential

The development of the geochemical potential concept commenced with the introduction — on the basis of CARTLEDGE's cationic potentials — of the concepts of anionic potential, complex anionic potential and compound potential (SZÁDECZKY-KARDOSS 1954).

The compound potential is essentially the arithmetic mean of the potentials of the cations and anions, calculated from the chemical formula of the compound. The compound potential is a geoenergetic parameter derived by assuming the additivity of the ionic potentials:

$$\psi = \frac{a \cdot \psi_1 + b \cdot \psi_2 + c \cdot \psi_3 + \cdots}{a + b + c + \cdots}$$

where ψ_1, ψ_2 and ψ_3 mean the ionic potentials of the individual cations and anions, respectively and a, b and c mean the number of the different ions in the molecule.

The compound potential can be considered as a parameter indicating the coordinates of crystallization. In most cases it is possible to derive from it the relative tensions of fusion and solubilities, respectively, of the different components of a system, i.e. the relative positions of the individual points of the surface of crystallization. By developing the potential calculations, a great deal of experimental work can be saved. We can compute the hardly determinable or indeterminable melting or dissolving properties of special substances, such as compounds dissociating or undergoing alteration prior to fusion. We can check experimental results and demonstrate some hitherto unknown processes of dissociation and alteration. Consequently, the anionic and compound potentials serve to characterize and to systematically interpret chemical processes even in lack of thermochemical data, or in cases when the lack of knowledge of exact pressure and temperature parameters makes impossible the application of the standard methods of thermochemistry.

In the knowledge of the compound potential it is possible to establish immediately the theoretical crystallization sequence and more generally, the behaviour of closed systems under various circumstances, e.g. of cooling, or evaporation. Crystallization takes place in the order of decreasing compound potentials, i.e., in the course of crystallization, the ions giving the greatest compound potential at a given instant will be precipitated. Therefore, the knowledge of the compound potential is equivalent with the knowledge of the theoretical sequence of crystallization under varying circumstances of p, t and

c. This makes possible the construction of the surface of crystallization even under highly variable conditions.

The compound potential of a given compound is not an invariable constant, on the contrary, it is subject to modification due to certain internal and external factors (SZÁDECZKY-KARDOSS 1955).

2. The factors determining the compound potentials and the calculation method

Lately, significant progress has been made in calculating the more exact values of the compound potentials (GRASSELLY 1958, 1959 a, b, c).

The factors to be taken into consideration when calculating the compound potentials are briefly discussed below:

a) *The variable complex anionic potentials.*

Most striking is the variation of the complex anionic potentials from compound for one and the same complex anion. This variation is especially important in the case of the silicate anion, playing a decisive role in igneous crystallization. In anisodesmic lattices these changes depend primarily on the change of the ionic distances within the complex anion. In mesodesmic structures like silicates and borates besides the change of the ionic distances, the variation of the complex anionic potential with the degree of silification proves to be considerably more significant (GRASSELLY 1958, 1959).

The behaviour and properties of the SiO_4^{4-} anion vary with the degree of linkage of SiO_4-tetrahedra as proved by results of the infrared spectroscopy and by examinations based on thermochemical data. Both experimental results and the theoretical considerations show that the properties of the SiO_4 tetrahedra change with the degree of polymerization from the nesosilicates toward the tectosilicates. To characterize these changes the ψ/SiO_4 potentials were introduced as the expression of the variable complex anionic potentials relating to the SiO_4 tetrahedron, equally present in all silicates with variable properties. These values are characteristic of the individual groups of silicates and show the influence of both the ionic distances and the degree of polymerization on the change of the complex anionic potential.

These values of the ψ/SiO_4 potential are capable of expressing the relative stability of the silicate anions and their decreasing order indicates the probable sequence of formation of the silicates (GRASSELLY 1959).

The changes of the properties of the SiO_4 group, viz. the degree of polarization of the oxygen atom, the nature of the Si—O bond, and the stability of the silicate anion may be readily expressed from the nesosilicates to the tectosilicates by the various ψ/SiO_4 potentials, which is an advantage when computing the compound potentials of different silicate minerals.

Table 1

Si : O	Structure type	Anion	ψ/SiO_4 potential, assuming an average Si—O distance of 1.62 Å
1 : 4	Nesosilicates	SiO_4^{4-}	1.40
1 : 3.5	Sorosilicates	$Si_2O_7^{6-}$	1.22
1 : 3	Cyclosilicates Inosilicates	$Si_3O_9^{6-}$, $Si_6O_{18}^{12-}$	1.05
1 : 3	pyroxenes	SiO_3^{2-}	1.05
1 : 2,75	amphiboles	$Si_4O_{11}^{6-}$	0.96
1 : 2,5	Phyllosilicates	$Si_2O_5^{2-}$	0.87
1 : 2	Tectosilicates	$Al_2Si_2O_8^{2-}$ $AlSi_3O_8^{1-}$ $Si_4O_8^{0}$	0.80 0.74 0.70

b) *The coordination number of the cations.*

The change of the coordination number also influences the ionic radius and thus indirectly the ionic potential and the compound potential as well. The ionic radii valid for a given coordination number may be obtained by multiplying the ionic radius values determined for sixfold coordination, with coefficients determined by PAULING for the different coordination types. The coefficients will vary in dependence of BORN's repulsion exponent for the given ion.

The changes in ionic potential caused by the radius changes due to changes in the coordination number are shown in Table 2.

The coordination number is especially useful when dealing with the *modifications of one and the same compound.* Thus, e.g. in the case of the two varieties of $CaCO_3$, calcite and aragonite, the coordination number of the Ca^{2+} ion is different on the other hand, according to X-ray investigations, the C—O distance within the complex anion CO_3^{2-} is also different. Similarly, in the case of the γ and α' modifications of Ca_2SiO_4 the coordination number of Ca^{2+} is likewise different, entailing differences in ionic radii and ionic potentials. The compound potential will express the difference between these modifications as shown in Table 3.

The changes of the compound potential may be demonstrated also for different modifications of polymorphic compounds, if the ionic or atomic distances change even if the coordination numbers remain unchanged, as e.g., for the different crystalline modificatons of SiO_2.

Having introduced the variable ψ/SiO_4 potential it seems to be more expedient when calculating the compound potentials, to consider as a unit, instead of the complex silicate anion given by the chemical formula, the SiO_4 tetrahedron of variable properties, present in all silicates and to regard

Table 2

The variation of the ionic potential of some ions in dependence on the coordination number

Ion	Coordination number			
	4	6	8	12
S^{6+}	21.42	19.98		
P^{5+}	15.15	14.30		
Cr^{6+}	12.24	11.53		
As^{5+}	11.52	10.85		
Si^{4+}	10.25	9.52		
V^{5+}	9.09	8.50		
Ge^{4+}	8.00	7.56		
Al^{3+}	6.25	5.88		
Ti^{4+}	6.25	5.88		
Be^{2+}	6.06	5.71		
Ga^{3+}	5.17	4.83		
Cr^{3+}	5.08	4.76	4.41	
Zr^{4+}	5.40	5.08	4.70	
Fe^{3+}	5.00	4.68	4.34	
Mg^{2+}	3.22	3.03	2.81	
Fe^{2+}	2.85	2.70	2.50	
Zn^{2+}	2.85	2.70	2.50	
Mn^{2+}	2.66	2.50	2.32	
Ca^{2+}		2.02	1.87	1.81
Ba^{2+}		1.49	1.38	1.33
Na^{+}		1.03	0.96	0.92
K^{+}		0.75	0.69	0.67
Rb^{+}		0.68	0.63	0.60

Table 3

Compound	Modification and structure type	Coord. number	Ψ_{M^+}	Ψcomplex	Ψcompound
$CaCO_3$	Calcite (calcite)	6	2.02	0.82	1.42
	Aragonite (aragonite)	9	1.90	0.81	1.35
Ca_2SiO_4	$\gamma-Ca_2SiO_4$ (olivine)	6	2.02	1.40*	1.81
	$\alpha'-Ca_2SiO_4$ (K_2SO_4)	9	1.90	1.40*	1.73

* The average complex anion potential of SiO_4 in the nesosilicates, in lack of knowledge of the appropriate value for the compound in question.

as its anionic potential the ψ/SiO_4 parameter characteristic of the given type, taking it as many times as indicated by the chemical formula; beside the structure type also the coordination number of the cation is to be taken into consideration.

Table 4

Modifications	Si—O distance in Å	Compound potential
β-tridymite	1.54	0.74
β-cristobalite	1.57	0.73
α-quartz	1.61	0.71

Thus, e.g., in the case of diopside, considering both the coordination numbers of the cations and the structure type, the following compound potential is obtained:

$$\psi_{Ca^{[8]}Mg_9^{[6]}Si_2O_6} = \frac{1 \times 1{,}87 + 1 \times 3{,}03 + 2 \times 1{,}05}{4} = 1{,}74$$

Similarly, the compound potential of tremolite is determined as follows:

$$\psi_{Ca_2^{[8]}Mg_5^{[6]}Si_8O_{22}(OH)_2} = \frac{2 \times 1{,}87 + 5 \times 3{,}03 + 8 \times 0{,}96 + 2 \times 0{,}75}{17} = 1{,}75$$

The compound potential of orthoclase is:

$$\psi_{K^{[10]}AlSi_3O_8} = \frac{1 \times 0{,}68 + 4 \times 0{,}73}{5} = 0{,}72$$

c) *The electronegativity values and the compound potentials of the silicates*

The compound potentials of the tectosilicates are, on the basis of the new as well as the earlier values, close to that of quartz, owing probably to the circumstance that in the tectosilicates the decisive role in determining the structure is played by the three-dimensional Si—O framework and the role of the cations is only secondary as these occupy the interstices of the anionic framework and do not essentially influence the compound potential characteristic of the SiO_2 lattice. This interpretation seems to be plausible; the more so, as the nature of the silicates is determined from the energetic point of view by the Si—O bonds. In the tectosilicates the bond between the alkalis and oxygen is much weaker than the Si—O bond and the ionic potential of the alkalis is low because of their small polarizing ability, so that they do not change

essentially the initial value, the compound potential of the cation-free tree-dimensional lattice.

However, in other silicates the role of the cations becomes more important. The cations occur not only in the interstices of the Si—O framework, but also in a connecting function between the SiO_4 tetrahedra and tetrahedron groups, chains and layers. In the neso- and inosilicates the cations of higher polarizing ability and higher ionic potential (Mg, Fe) have a greater influence on the compound potential.

Table 5

Minerals		Compound potential	
		New value	Earlier value
Anorthite	$Ca^{[6]}Al_2Si_2O_8$	0.84	1.52
Nepheline	$Na^{[8]}AlSiO_4$	0,84	1,44
Albite	$Na^{[6]}AlSi_3O_8$	0.78	1.41
Leucite	$Na^{[10]}AlSi_2O_6$	0,73	1.38
Orthoclase	$K^{[10]}AlSi_3O_8$	0.72	1.38
Quartz	SiO_2	0.71	1.38

In computing the complex anionic potential for compounds with complex anions it is possible to take into consideration to some extent also the bond type within the complex anions. The nature of the Si—O or S—O bond is expressed by the complex anionic potential inasmuch as the computation is carried out not with the sum of ionic radii (ionic model) but with the effective ionic distances, smaller than the sum of the ionic radii in dependence on the covalency of the bond type.

The refining of the compound potential computation necessitates the consideration of the ionic or covalent type of the bond, too. According to investigations by PAULING, the difference in the electronegativity values between oxygen and the appropriate cations give at least an approximate indication of the percentage of ionic bonding in the structure. Consequently, we can introduce into the compound potential formula the electronegativity values. It was to be emphasized, however, that these values are not quite accurate and that the electronegativity values cannot be regarded as constant. It is namely known even in the case of the silicates that the oxygen atom changes its degree of polarization from the nesosilicates toward the tectosilicates and varies also its electronegativity against the cations.

On the basis of the above-said, the compound potential of a silicate of the general formula $A^{[6]}B^{[8]}Si_2O_6$ may be computed by applying the formula

$$\psi_{\text{compound}} = \frac{a \cdot \psi_{A^{[6]}} \cdot (x_0 - x_A)\, b + \cdot \psi_{B^{[8]}} \cdot (x_0 - x_B) + c \cdot \psi(SiO_4) \cdot (x_0 - x_{Si})}{a + b + c \cdots}$$

In this formula, we have taken into consideration:

a) the coordination number of the cations

b) the degree of silification, the type of the linkage of the SiO_4 tetrahedra

c) the ionic-covalent character of the bond.

In Table 6 the first value is the compound potential. In it only the coordination number of the cation and the structure type of the silicate has been taken into consideration. The second column gives the compound potentials taking into account also the bond type on the basis of the values of electronegativity. It is seen that the differences can be quite significant (see also chapter 5).

However, already in the earlier values (Table 5) the bonding characters was incorporated to some extent.

Table 6

Mineral		ψ_c	$\psi_{c'}$
Phenacite	$Be_2^{[4]}SiO_4$	4.50	8.87
Zircon	$Zr^{[8]}SiO_4$	3.05	6.12
Forsterite	$Mg_2^{[6]}SiO_4$	2.48	5.44
Fayalite	$Fe_2^{[6]}SiO_4$	2.26	4.12
Enstatite	$Mg_2^{[6]}Si_2O_6$	2.05	4.40
Hypersthene	$Mg^{[6]}Fe^{[6]}Si_2O_6$	1.96	3.55
Augite	$Ca^{[8]}(Mg, Fe, Al)^{[6]}Si_2O_6$	1.96	4.05
Diopside	$Ca^{[8]}Mg^{[6]}Si_2O_6$	1.74	3.78
Hornblende	$(Ca^{[8]}, Na^{[12]})_2(Mg, Fe, Al)_5^{[6]}Si_8O_{22}(OH)_2$	1.84	3.64
Anthophyllite	$(Mg, Fe)_7^{[6]}Si_8O_{22}(OH)_2$	1.72	
Tremolite	$Ca_2^{[8]}Mg^{[6]}Si_8O_{22}(OH)_2$	1.65	
Muscovite	$K_2^{[12]}Al^{[6]}(AlSi_3)O_{10}(OH)_2$	1.96	3.77
Biotite	$K^{[12]}(Mg, Fe, Mn, Al)_3^{[6]}(AlSi_3)O_{10}(OH)_2$	1.64	3.21
Phlogopite	$K^{[12]}Mg_3^{[6]}(AlSi_3)O_{10}(OH)_2$	1.49	3.13
Anorthite	$Ca_8^{[6]}Al_2Si_2O_8$	1.01	2.11
Nepheline	$Na^{[8]}AlSiO_4$	0.84	1.79
Albite	$Na^{[6]}AlSi_3O_8$	0.74	1.55
Leucite	$K^{[10]}AlSi_2O_6$	0.73	1.47
Orthoclase	$K^{[10]}AlSi_3O_8$	0.72	1.39
Quartz	SiO_2	0.70	1.19

The upper indices indicate the coordination of the cation.

d) *The difference between the chemical formula and the actual composition*

The starting point of compound potential calculations is generally the chemical formula. However, the true composition of the minerals is in most cases different from the theoretical one, as the mineral may contain variable amounts of foreign constituents and trace elements. The chemical potential based on the formula may be regarded as an average value, in most cases accurate enough for general characterization of the processes. However, in exact compound potential calculations it is necessary to consider the true composition. Let us refer here first to isomorphous mix-crystals, to solid solutions. Thus, e.g., the compound potential of the individual members of the plagioclase series may be readily written up when considering the albite-anorthite ratio on the basis of Fig. 1, after closer determination of the plagioclases of the rock in question. A similar proceeding may be expedient, e.g., in the case of olivine. Examining the olivine of the rock in question and establishing the Fe_2SiO_4 : Mg_2SiO_4 ratio, the compound potential actually valid for the olivine occuring in the rock, can be given. This value differs naturally from the average value used in general.

3. The interpretation of Bowen's reaction series of silicate minerals on the basis of the compound potentials and other factors influencing the sequence of the igneous crystallization

It has been shown that in the course of igneous crystallization the minerals are formed in the order of decreasing compound potentials (SZÁDECZKY-KARDOSS 1954, 1955).

The compound potentials listed in Table 6 show a continually decreasing sequence of ionic potentials from the neso- to the tectosilicates, in agreement with the fact that in BOWEN's reaction series the formation of minerals commences with the nesosilicates and proceeds through all the intermediate stages toward the tectosilicates.

However, comparing the new compound potentials with those furnished by the first approximation, it is seen that the earlier compound potentials have yielded two sequences, in agreement with the two group of BOWEN's series. The one that of the melanocratic rock forming minerals, varies from the nesosilicates toward the phyllosilicates with continually decreasing compound potentials, from 2.12 for olivine to 1.47 for biotite. The other sequence is that of the leucocratic rock-forming minerals, within which the structure type remains the same (tectosilicates and muscovite), and only the cation and the Al : Si ratio, respectively changes from anorthite quartz, with an appropriate decrease of the compound potentials from 1.52 for anorthite to 1.38 for quartz.

The new compound potentials, in which the coordination number of the cations, the structure type and the character of the bonds have been taken into consideration, give, on the contrary, a uniform sequence from the nesosilicates to the tectosilicates, in which the tectosilicates range after the phyllosilicates. The question arises whether this new sequence is confirmed by observations and whether it can be explained that although in the new sequence the tectosilicate succeed the phyllosilicates, in the crystallization of a gabbroidal magma anorthite and basic plagioclases in general will begin to form about simultaneously with inosilicates.

As regards the first problem it may be mentioned that with the variable SiO_4 complex anionic potentials it is possible to characterize the stability of the silicate anions of the individual structure types (GRASSELLY 1959). The decreasing order of the ψ/SiO_4 potentials, as computed for these silicate anions, gives at the same time the probable order of formation of the individual Si—O structure types. As in the silicates the Si—O bonds are strongest, and as the silicate structure is determined in the first place by the type of the linkage of the SiO_4 tetrahedra, it seems to be plausible that, even in determining the compound potentials the silicate anionic potential characteristic of the structure type in question, will play an important role.

Concerning the second problem we should like to recall that the compound potential of anorthite was 1.52 in the first approximation a value close to that of the inosilicates, while according to the new computation it is 1.01 (or 2.11, taking into consideration, also the electronegativity values), i.e., less than that of the phylosilicates. In the course of the normal differentiation of a gabbro-granite magma sequence the formation of the basic felspars commences about simultaneously with that of the inosilicates, namely of the pyroxenes, whereas the formation of orthoclase is about simultaneous with that of albite and quartz, respectively, while the series of the melanocratic components also ends with biotite and finally with quartz. The decreasing compound potential values of the first approximation represent this state.

However, the biotite-diorite series is apparently characterized by the early formation of biotite preceding that of diopside, hypersthene, amphibole, i.e., that of the inosilicates. In this case potash felspar is either entirely absent, or present in minute amounts only, as early-formed biotite has significantly lowered the K concentration in the melt. However, this can be directly explained neither by the first approximation, nor by the new sequence of compound potentials.

The compound potentials are considered as values indicating the theoretically possible sequence of crystallization. The sequence actually realized depends, however, besides the compound potentials, also upon other factors, such as the concentration and nature of the cations, the viscosity of the magma. The sequence of minerals in the order of the decreasing compound potentials

is only the theoretically probable succession of the minerals. It may be modified by other factors such as the concentration and nature of the cations present in the magma, since the silicate anions are present in vain in the magma at the beginning of crystallization, if the concentration of appropriate elements does not reach an adequate level. In such cases although a given compound, according to its compound potential value, could already form at a relatively early stage of crystallization, it will occur only at later stage when the cation, enriched in the residual liquid, reaches the appropriate concentration. The nature of the cations is also essential, since the cations breaking down the polymerized silicate anions into smaller units diminish the viscosity of the magma.

Thus it can be presumed that the viscosity of a melt rich in Fe and Mg of greater polarizing ability is lower than that of a melt relatively rich in Ca, Na, K as the latter will not destroy the anion framework and will occupy the interstices of these.

In our opinion, the viscosity of the magma has to be treated apart from the point of view of the sequence of crystallization, both the ionic diffusion and velocity of crystallization are directly related to viscosity. Ionic migration and crystallization take place more readily in a basic magma of relatively low viscosity containing rather simple silicate anions than in acidic magmas of higher viscosity relatively rich in three-dimensional Si—O—Al frameworks. It is probable that in acidic magmas the plagioclases and in general the tectosilicates will form only somewhat later than inosilicates as the larger alkali ions migrate less readily in the viscous magma. On the contrary, in a basic magma of low viscosity the formation of tectosilicates is favoured. It has been shown elsewhere that whereas migration in an aqueous solution is governed by the hydrated ionic radii, in melts the ionic radii determined in the space lattices will presumably be decisive [Szádeczky-Kardoss, 1958].

Taking into consideration, at least semi-quantitatively, the influences of the factors mentioned above, there arise new possibilities of deriving more accurate values of "rock potentials" too [Szádeczky-Kardoss, 1955]. The new compound potential values represent already a better approximation to this problem.

The potentials show a gradual decrease from the minerals of ultrabasic rocks through the minerals of basic, acidic, alkali and finally pegmatitic rocks up to the pneumatolic limit. Here the potential value take a sudden rise, only to decrease again gradually in the mineral formations of the hydrothermal stage. The sudden potential jump indicates the end of the crystallization of the silicate melt. With the pneumatolytic stage, there commences the crystallization of an aqueous solution system, hardly miscible with the foregoing one.

In plotting the empirically determined successions of formation of some of the metasomatic ore deposits and of the pneumatolytic and hydrothermal veins in the function of compound potentials, a periodic oscillation is frequently

encountered. These oscillations, representing the phenomena of recurrence and rejuvenation of ore genesis offer a deeper insight into the nature and to some extent into the temperature changes of the individual phases of ore formation, of the repeated invasions of ore-bearing solutions. Thereby, it is possible to solve some of the problems of ore formation on a more stable basis. (Investigations in this line have already been carried out by TOKODY in the Tokaj Mountains.)

The crystallization of minerals does not invariably start on the same energy level. When entering a lattice complex ions occurring in solutions or melts

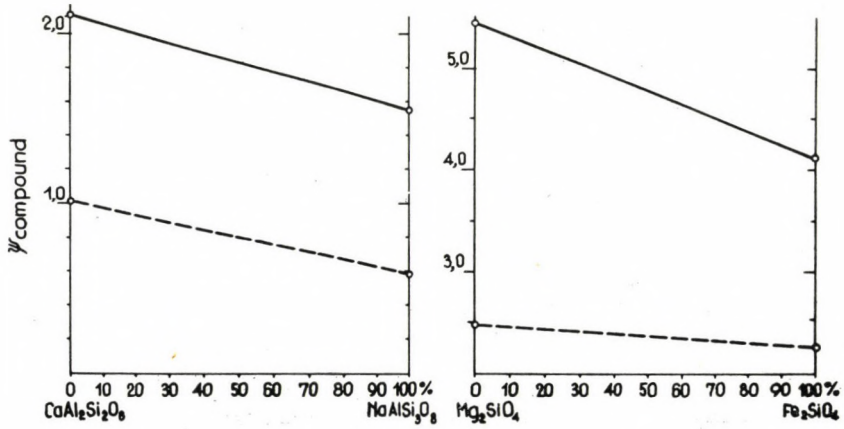

Fig. 1. Change of the compound potential vs. composition in the plagioclase and olivine series (broken lines are ψ_c values of Table 6)

are more or less intensely polarized by external cations, they undergo a deformation entailing the loss of part of their complex nature. Thus, the values characterizing more or less accurately the crystallization sequence and the stability of the crystal lattice such as the point of fusion, the solubility and hardness, frequently show no parallelism. In such cases the potential computation may be applied as a connecting link between processes of crystal chemistry and geochemistry, as the concept of "binary potentials" is able to show up numerically the parallelism — or the lack of such — between the mentioned values of solubility, point of fusion, hardness and sequence of formation.

4. The sedimentary processes and the potential concept

GOLDSCHMIDT was the first to establish the main lines of the distribution of sedimentary rocks on a geochemical basis, namely by CARTLEDGE's ionic potentials. The relationship found by him express that under sedimentary

circumstances the elements of higher ionic potentials are less soluble than those of lower potentials. On this basis, GOLDSCHMIDT has distinguished resistates, hydrolizates, carbonates and evaporites. It has remained, however, unexplained why some of the highest-potential elements, the sedimentary phosphates, nitrates, borates occur in the group of resistates, i.e., of the minerals first precipitated. A further contradiction was that apparently a number of elements were not precipitated at all in the fields indicated by their cationic potentials. The introductions of the anionic and complex anionic potentials has dispelled these contradictions and led to the completions of the potential system of sedimentary rocks. It is true that phosphorus, nitrogen and boron occur in the resistate field, but because of their very high potentials these elements will, when still in solution, form complex phosphate (nitrate, borate) anions of smaller potential. These ions are more correctly characterized by their complex anionic potentials than by the simple cationic potentials (SZÁDECZKY-KARDOSS 1955 a, GRASSELLY 1960) — The correct potential values thus obtained will indeed correctly characterize the occurence and behaviour of these elements.

The circumstance that some elements do not precipitate where expected is due to the fact that precipitation depends not only on the properties of the ion in question, but also on those of the other ion which enters the compound. Consequently, the circumstances of precipitation are a function of the compound potential rather than of the ionic potential. If no appropriate partner is present, there will eventually occur no precipitation at all. Thus, the diagram of cationic potentials of the elements is complete only together with the diagram of anionic potentials. The main groups are delimited by the diagram of anionic potentials as readily as by that of cationic potentials. This fact, which led to some misunderstandings (LEUTWEIN and DOERFFEL 1956), was placed in a correct light by SZÁDECZKY-KARDOSS (1959). Interesting correlations were established among the relative stability relations of the different oxyanions, the position of their central cation in the periodic system, the chemical and crystallochemical behaviour of these tetrahedral oxyanions and the geochemical classification of the sediments, denoting the complex anionic potentials in function of the electrostatic energies calculated on the basis of the ionic model (GRASSELLY 1959).

The systematic determination of the compound potentials of rock salt minerals and the definition of their sequence of formation on this basis offers some interesting possibilities, especially when combined with the highly developed knowledge of salt deposits.

By the potential concept it is possible to express also the adsorptive binding of some of the elements in sedimentary systems. The potential also serves to some extent to predict the concentrations of elements in the individual geophases. Low-potential elements, readily soluble, can reach higher concen-

tration in solution than the high-potential ones. The application of potential computations to phenomena of migration has been dealt with elsewhere (SZÁDECZKY-KARDOSS 1959). In this respect the references of P. ESKOLA to the application of potentials to problems of granite formation are of importance. Therefore — although the migration and precipitation of elements depends, beside the bonding forces, also on the concentration parameters, the potential values are capable of giving a picture of the mineral formations and minerogenetic relationships of the entire system of rocks and ores.

5. The atomic potential

It has been mentioned that to develop further the potential concept it was necessary to extend the compound potential calculation to atoms in covalent bond. Namely, for larger ions with octet or eighteen-electron configurations the ionic potential values have no validity as these ions form predominantly covalent bonds. It has been presumed that the chemical bonding forces are determined, in the case of covalent and metallic bonding, too, essentially by the same two factors as in the case of ionic bonds, i.e., by the number of electrons per atom and by the action radius of the atom occuring in the bond. Therefore, in the case of atom lattices and covalent bonds the number of valence electrons is substituted by the number of electrons partaking in the bond, while the ionic radii are substituted by the so-called atomic radii. The values derived are in unavoidable analogy to the term ionic potential, called atom potentials and the values computed out of these for the compounds, atomic compound potentials (SZÁDECZKY-KARDOSS 1955). However, in the case of atoms in covalent bond the problem arises whether it is appropriate to speak of a potential at all, since the potential here has undoubtedly a significance differing from that of the electrostatic potential in the case of a pure ionic bond. In any case, a bond force arises in covalent bond, too, and therefore there must exist a potential as well (KLIBURSZKY 1958).

The principle applied here rests on the presumption that the covalent force depends on the ratio of the number of electrons partaking in the bond vs. the atomic radius. This assumption was proven by computations which yielded values corresponding to the common sequence of crystallization in case of a simultaneous formation of minerals of ionic, metallic and covalent bonding.

In principle the computation is quite simple in the case of mixed bond types, too. The effective compound potential may be derived as a linear function, i.e. by simple ratio computation, from the ionic and atomic compound potentials by considering the bond polarity (covalence percentage) as determined from electronegativity. Thus the extreme, pure bond types are considered to involve an integral number of electrons, in agreement with quantum theoretical requirements. The interpolation, on the other hand, gives a possibility

to numerically evaluate a polarization which can otherwise be taken into consideration with great differences only.

The degree of bonding polarization being a function of temperature, potential computation also gives a possibility of the appropriate consideration of the temperature factor.

As it is seen, the application of the potential concept makes possible to reduce the different types of chemical bond to one common feature. Of course, potential computations have not been extended to van der Waals bonds. Which are no true chemical bonds.

The potential concept, by taking as its basis the number of valence electrons, and the atomic and ionic radii, respectively, reposes on two basic chemical realities, namely the valence concept and the mutual distance of the atoms and ions, directly measurable by X-ray methods. In this manner although conscious of the up-to-date theories of chemical bond and its partly still embryonal assumption, e.g. orbital hybridization, resonance, etc. — the potential concept is essentially independent of the same, as these concepts do but influence its "wording" at any time. Thus, the two basic sets of values of potential computation are directly observed facts just like the calorimetry results forming the basis of thermodynamics. Moreover, the data used in potential computations possess a concrete geometrical connotation wherefore they are applicable in space geometry and thus offer a direct connection with crystal chemistry.

REFERENCES

Eskola, P.: Comptes Rend. de la Soc. géol. de Finlande **XXIX,** 85, 1956. — Grasselly, Gy.: Acta Geol. Acad. Sci. Hung. **5,** 293, 1958. — Grasselly, Gy.: Acta Miner. Petr. Univ. Szegediensis **12,** 3, 1959a. — Grasselly, Gy.: Acta Miner. Petr. Univ. Szegediensis **12,** 31, 1959b. — Grasselly, Gy.: Acta Miner. Petr. Univ. Szegediensis **12,** 51, 1959c. — Grasselly, Gy.: Acta Miner. Petr. Univ. Szegediensis **12,** 61, 1959d. — Grasselly, Gy.: N. Jb. Miner., Abh. **94,** 1075, 1960. — Kliburszky, B.: Acta Geol. Acad. Sci. Hung. **5,** 313, 1958. — Leutwein, F. und Doerffel, K.: Geologie **5,** 65, 1956. — Szádeczky-Kardoss, E.: Acta Geol. Acad. Sci. Hung. **2,** 285, 1954. — Szádeczky-Kardoss, E. Acta Geol. Acad. Sci. Hung. **3,** 105, 1955a. — Szádeczky-Kardoss, E.: Acta Geol. Acad. Sci. Hung. **3,** 105, 1955a. — Szádeczky-Kardoss E.: Acta Geol. Acad. Sci. Hung. **3,** 163, 1955b. — Szádeczky-Kardoss, E.: Geokémia (Geochemistry), Akadémiai Kiadó, Budapest, 1955c. — Szádeczky-Kardoss, E.: Acta Geol. Acad. Sci. Hung. **5,** 351, 1958a. — Szádeczky-Kardoss, E. Acta Geol. Acad. Sci. Hung. **5,** 360, 1958b. — Szádeczky-Kardoss, E.: Freiberger Forschungshefte C. **58,** 66, 1959.

О НЫНЕШНЕМ ПОЛОЖЕНИИ РАЗВИТИЯ КОНЦЕПЦИИ О ПОТЕНЦИАЛАХ В ГЕОХИМИИ

Е. САДЕЦКИ-КАРДОШШ и ДЬ. ГРАССЕЛЛИ

Резюме

Понятие геохимического потенциала позволяет интерпретировать геохимические процессы однозначно, начиная с возникновения мобильной или жидкой фазы и кончая с

малоподвижными или стабильными твердыми соединениями, даже в тех случаях, когда не имеются в распоряжении термохимические данные. При этой концепции применяются лишь атомные константы в виде катионных, анионных, комплексно-анионных потенциалов и потенциалов соединений. Потенциал соединений является по существу средней арифметической величиной потенциалов катионов и анионов соединений. Он позволяет принимать во внимание и координационное число соединения (таблица 2), т. е. различные модификации одного и того же самого соединения (таблицы 3 и 4), а также ионный или ковалентный тип связи (таблица 6).

В большинстве случаев по потенциалу соединения можно также судить о сравнительных напряжениях расплавления и растворимости. При помощи потенциалов соединения можно теоретически установить вероятную последовательность кристаллизации в магматических породах в различных условиях, а также в осадочных породах. Однако, фактическая последовательность кристаллизации может изменяться другими факторами, а именно — концентрацией и природой присутствующих в магме ионов, вязкостью магмы и т. п.

CONFRONTATION OF COMPLEX ANIONIC POTENTIALS AND COMPOUND POTENTIALS WITH THERMOCHEMICAL DATA

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The complex anionic potentials and the compound potentials calculable from atomic data have been widely used so far to interpret geochemical processes even in the absence of thermochemical data. The present paper mentions some of the correlations of the above-mentioned potential values and thermochemical data that is correlations between anionic potentials and heat of hydration and that between the compound potentials and heat of formation. So beside the extension of the field of application of these potentials we may approach a more precise physical interpretation of the aforesaid potentials.

Introduction

The compound potential introduced by SZÁDECZKY-KARDOSS (1954, 1955) may be considered as the arithmetic mean of the potentials of the ions (cations and simple or complex anions) constituting a compound. Compound potentials are readily calculated from atomic data (ionic radius and charge) taking into consideration the coordination number of the cations, the ionic distances within the complex anions and — in the case of silicates — the degree of silification as discussed by SZÁDECZKY-KARDOSS and GRASSELLY (1965). These compound potentials proved useful in characterizing the properties and behaviour of diverse compounds even if no thermochemical data are available for the compounds in question. Therefore, the compound potentials may be widely used to interpret geochemical processes.

The introduction of the concept "compound potential" is thought of as justified not only by mineralogists and geochemists but also by physicochemists — although the latters still consider the compound potential as a rather arbitrarily defined, empirical value — because several remarkable and plausible correlations were shown up in the papers dealing with atomic and compound potentials. Furthermore should it be possible to interpret the correlations stated by the geochemical potential concept based on the ionic, atomic and compound potentials, respectively, a more profound insight would be gained into geochemical processes since in contrast to thermodynamics correlations revealed by the potential concept offer also some conclusions regarding the mechanism of the processes.

It seems to be evident that the more correlations there are discovered between termochemical data and the corresponding potential values, the more closely one can approach the unequivocal definition of the compound potential also from the physical point of view, the more completely the physical meaning of this concept will be revealed.

While CARTLEDGE (1951) dealt in his paper published in 1951 with the problem of the correlation between the heat of formation of given compounds and the corresponding cationic potentials, this paper represents the first effort to establish correlations between complex anionic and compound potentials and thermochemical data.

Correlation between the heat of hydration and the anionic potential of some complex anions

In one of his previous papers (1959) the author proposed a simple method to determine the effective radius of the complex anions bearing in mind that the tetrahedral complex anions in the crystal lattice can hypothetically be substituted by a spherical ion, i.e. by a sphere, the surface and volume of which are nearest to the volume and effective surface of the tetrahedral oxyanion (from the point of view of the bond and isomorphy relations, respectively). The radius of this sphere can be considered as the effective radius of the complex anion. The anionic potentials calculated with these radii differ from the potential values used at present.

It is known that the heat of hydration of ions is a function of the radius of the ions:

$$L = z^2 \cdot f(r).$$

In his work dealing with the thermochemistry of complex compounds, JAZIMIRSKY (1956) illustrated diagrammatically the correlation between that heat of hydration and the radii of the anions and cations, respectively, plotting the L/z^2 values in kcal against the radii given in Å.

The correlation between the heat of hydration and the complex anionic potential is obvious in Fig. 1. The once-, twice and trice-charged complex anions are separated from each other and the correlation within the individual groups is fairly linear. Moreover, some connection with the position of the central cations in the periodic table is also recognized. The points corresponding to the BO_3—CO_3—NO_3 anions are arranged along a fairly straight line. It would be expected that the points corresponding to the PO_4—SO_4—ClO_4 anions will also be arranged along a straight line. The lines connecting the points of BO_3—CO_3 and those of PO_4—SO_4 and AsO_4—SeO_4, respectively, intersect in one point. The point corresponding to the ClO_4 anion should be expect to fall

Table 1

Complex anion	Thermochemical radius Å	Effective radius Å	Anionic potential	L	L/z^2
				kcal	
NO_3^-	1.89	1.76	0.56	71	71
ClO_4^-	2.36	2.09	0.47	50	50
MnO_4^-	2.40	2.16*	0.46	49	49
JO_4^-	2.49	2.24	0.44	40	40
CO_3^{2-}	1.85	1·81	1.10	317	79
SO_4^{2-}	2.30	2.12	0.94	241	60
CrO_2^{4-}	2.40	2.16	0.92	229	57
SeO_4^{2-}	2.43	2.18*	0.91	224	56
MoO_4^{2-}	2.54	2.28*	0.87	216	54
TeO_4^{2-}	2.54	2.28*	0.87	216	54
WO_4^{2-}	2.57	2.31*	0.86	202	50
BO_3^{3-}	1.91	1.96	1.53	760	84
PO_4^{3-}	2.38	2.14*	1.40	550	61
AsO_4^{3-}	2.48	2.27	1.32	530	54

* The effective radii marked (*) were derived from the corresponding thermochemical radii on the basis of the relationship $R_{effective}/R_{thermochemical} = 0.9 \pm 0.02$. The L/z^2 values calculated by JAZIMIRSKY are shown vs. the complex anionic potentials computed from the effective radii in Fig. 1.

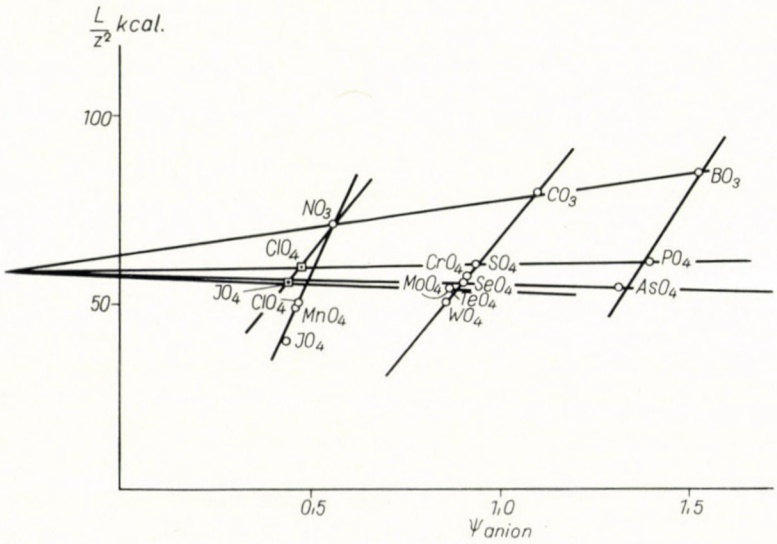

Fig. 1. Heat of hydration of some complex anions vs. complex anionic potential

on the line connecting the points of SO_4—PO_4. However, this would require a heat of hydration of 59—60 kcal. for ClO_4 instead of the 50 kcal. given by JAZIMIRSKY (1956). The point corresponding to the JO_4^- anion would fall on the line connecting the point of TeO_4 with the common intersection point only, if the heat of hydration of JO_4^- were 54 kcal instead of the 40 kcal. given by JAZIMIRSKY.

It is to be noted, however, that the heat of hydration of the JO_4^- anion as given in the paper referred to, is an uncertain value on the other hand the heat of hydration of the ClO_4^- anion as given in another paper by JAZIMIRSKY amounts to 55 kcal., much closer to the 59 kcal. estimated from the relationships outlined above.

The complex anionic potentials — as it is known — can be calculated from atomic data, from the ionic distances determined by X-rays. By means of the relationship between the heats of hydration and the complex anionic potentials as outlined above, it seems possible to estimate or to correct some missing or uncertain heats of hydration of complex anions in the possession of a few accurate heats of hydration on the basis of the exactly calculable complex anionic potentials. Further investigations into this problem are in progress.

Correlation between heat of formation and compound potential of some oxysalts

Dealing with the relationships between the heat of formation of alkali and alkali earth oxysalts on the one hand and the acidity and basicity of the oxides involved on the other, RAMBERG (1952 a) discussed some of the links between the thermochemical properties of these oxysalts and the position of their cations in the periodic table. In Fig. 2 the heats of formation per two gram equivalents of salt formed from acidic and basic oxides are illustrated after RAMBERG.

Fig. 2. was constructed by RAMBERG as follows: the ΔH values of all sulfates were plotted on a line which made an arbitrary angle with the abscissa. The alkali and alkaline earth metals were spaced along the vertical axis. Then horizontal lines were drawn through the points of the sulfate line, each line belonging to a given metal. The heats of formation of the perchlorates, nitrates, etc. were plotted on the line of the corresponding metal. The points representing the ΔH values fell close to straight inclined lines, each line connecting the ΔH points of the salt of a given acid.

From Fig. 2 it can be clearly stated that 1. the heat of formation of a salt of a basic oxide is the lower, the stronger the acidity of the acidic oxide, and 2. the heat of formation of a salt of an acidic oxide is the lower, the stronger the basicity of the metal oxide. Thus as summarized by RAMBERG (1952 a)

the heat of formation of oxysalts from the constituent oxides is a measure of the strength of the acids — when comparing the salts of the same metal — and a measure on the strength of the bases when comparing the salts of the same acids.

From Fig. 2 a further fact can also be derived, namely that most of the lines except the nitrates relative to the sulfates converge toward the upper right-hand corner, showing that base exchange reactions between two solid salts are exothermic if the most acidic anion combines with the most basic

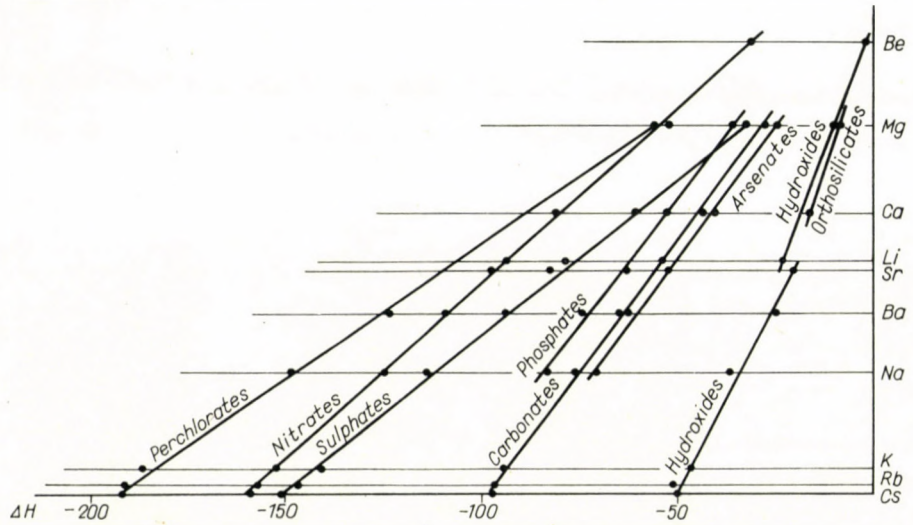

Fig. 2. ΔH of formation of some oxysalts from their basic and acidic oxides; given in kcal per two equivalents according to RAMBERG

metal oxide and the less acidic anion with the less basic metal, as was pointed out by RAMBERG.

In our opinion, should the compound potentials be considered as true indicators of the properties and behaviour of the compounds, the same relationships must hold between the compound potentials, too. To clear up the problem the reciprocal values of the compound potentials of alkali and alkaline earth perchlorates, sulfates, nitrates, etc., were plotted the way RAMBERG plotted the heats of formation. The reciprocal values were employed for the reason that the compound potential decreases with the increase of the negative value of the heat of formation, and the reciprocal value of the compound potential and the heat of formation change in the same direction.

In calculating the compound potentials the coordination numbers of the cations were also taken into consideration, as far as there were appropriate data available, that is, the ionic potentials of the cations were calculated with

Table 2

Compound	1.	2.	3.	4.	Compound	1.	2.	3.	4.
$Mg(ClO_4)_2$	1.32	0.75			$MgCO_3$	2.06	0.48		
$Ba(ClO_4)_2$	0.81	1.23			$CaCO_3$	1.56	0.64	1.51[9]	0.66
$NaClO_4$	0.75	1.33			$SrCO_3$	1.44	0.69	1.40[9]	0.71
$KClO_4$	0.61	1.63			$BaCO_3$	1.29	0.77	1.26[9]	0.79
$RbClO_4$	0.57	1.75			Li_2CO_3	1.34	0.74		
$CsClO_4$	0.53	1.88			Na_2CO_3	1.05	0.95		
$Mg(NO_3)_2$	1.38	0.72			K_2CO_3	0.86	1.16		
$Ca(NO_3)_2$	1.04	0.96	1.02[8]	0.98	Rb_2CO_3	0.82	1.21		
$Sr(NO_3)_2$	0.96	1.04	0.95[8]	1.05	Cs_2CO_3	0.76	1.31		
$Ba(NO_3)_2$	0.87	1.14	0.85[8]	1.17	$Mg_3(AsO_4)_2$	2.34	0.42		
$LiNO_3$	1.01	0·99			$Ca_3(AsO_4)_2$	1.73	0.57		
$NaNO_3$	0.79	1.26			$Sr_3(AsO_4)_2$	1.59	0.62		
KNO_3	0.65	1.53	0.63[9]	1.58	$Ba_3(AsO_4)_2$	1.42	0.70		
$RbNO_3$	0.62	1.61	0.60[9]	1.66	Na_3AsO_4	1.10	0.90		
$CsNO_3$	0.57	1.75	0.56[9]	1.78	$Mg_3(PO_4)_2$	2.38	0.42		
$BeSO_4$	3.32	0.30			$Ca_3(PO_4)_2$	1.77	0.56		
$MgSO_4$	1.98	0.50			$Sr_3(PO_4)_2$	1.63	0.61		
$CaSO_4$	1.48	0.67	1.45[8]	0.68	$Ba_3(PO_4)_2$	1.45	0.68		
$SrSO_4$	1.36	0.73	1.29[12]	0.77	Na_3PO_4	1.12	0.89		
$BaSO_4$	1.21	0.82	1.16[12]	0.86	Mg_2SiO_4	2.62	0.38		
Li_2SO_4	1.29	0.77			Ca_2SiO_4	1.95	0.51		
Na_2SO_4	1.00	1.00							
K_2SO_4	0.81	1.23	0.78[9]	1.28					
Rb_2SO_4	0.76	1.31	0.74[9]	1.35					
Cs_2SO_4	0.70	1.42	0.69[9]	1.44					

Plotting the data of Table 2 according to RAMBERG's method, one obtains Fig. 3.

the radius valid in the given structure. Failing such data, however, the cationic potentials were taken in related sixfold-coordination. The complex anionic potentials were calculated with the effective radii computed by the author (GRASSELLY 1959). The compound potentials are listed in Table 2. Column 1 comprises the compound potentials with the cations in sixfold-coordination, column 2 shows their reciprocal values, column 3 lists the compound potentials calculated by taking into consideration the coordination number of the cations in the given structure; finally column 4 comprises the reciprocal values of column 3.

It can be stated that the diagram of the compound potentials gives the same result as the plotting of the heats of formation. The points corresponding

to the compound potentials of the alkaline and alkali earth perchlorates, sulfates, nitrates, etc., fall along inclined straight lines and the lines converge just like those in Fig. 2. The sequence of the metals on the vertical axis is the same and the metals are arranged in the order of decreasing cationic potential from Be toward Cs. The compound potentials of the different Li salts are not plotted on Fig. 3. They would, however, fall along a horizontal line closely beneath the line of Sr.

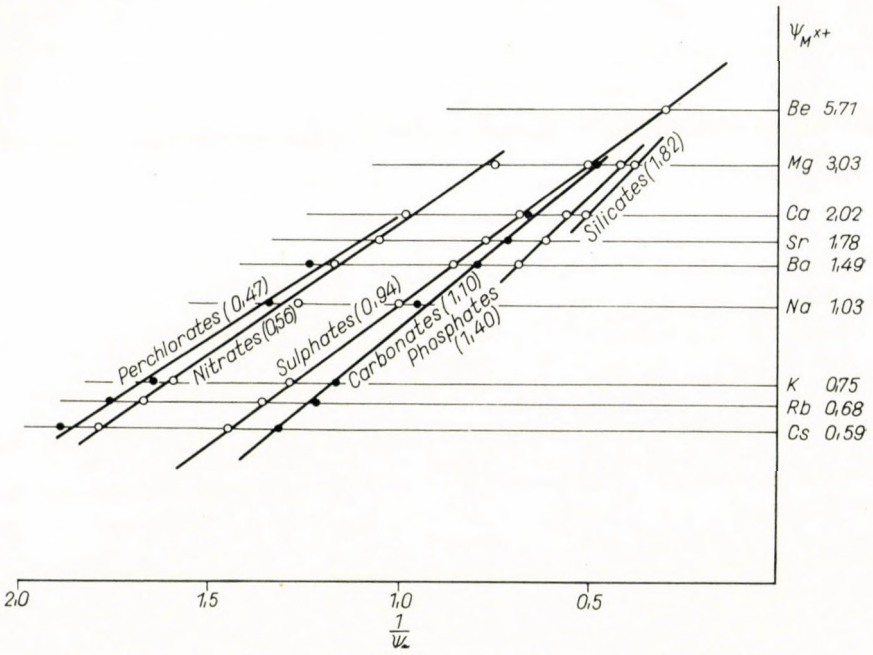

Fig. 3. Compound potential of the same oxysalts as in Fig. 2

Comparing the two figures (Fig. 2 and 3) the following differences can be established:

a) The lines representing the different perchlorates, nitrates, etc., on the basis of the reciprocal compound potential values follow each other on the order of the decreasing strength of the oxyacids: perchlorates — nitrates — sulfates, whereas the sequence obtained on the basis of the heats of formation is perchlorates — sulfates — nitrates. The correct sequence seems to be given by the compound potentials.

b) In the case of carbonates — arsenates — phosphates, the sequence obtained on the basis of the compound potentials corresponds to the order of increasing strength of the oxyacids whereas the heats of formation of these oxysalts, show no correlation with the strength of the oxyacids, since the sequence is: phosphates — carbonates — arsenates. It is to be noted that in Fig.

3, the arsenates are not plotted, since the line representing the arsenates would almost coincide with the line of the phosphates.

c) The inclined lines converge in both figures. However, in Fig. 3 compounds arranged according to their compound potential values do not show such irregularities as the ΔH values of the different oxysalts, mentioned also by RAMBERG.

In Fig. 3 the numbers beside the cations are the cationic potentials, whereas the numbers in parentheses beside the individual compounds are the corresponding complex anionic potentials. As it may be seen, the different Be-, Mg-, Ca-, etc., salts are arranged vertically in the order of decreasing cationic potential and the compound potential increases (its reciprocal value decreases) from the Cs-salts toward the Mg-salts for salts of the same acid, whereas for salts of the same metal the succession of the salts: perchlorates — nitrates — sulfates — carbonates — phosphates — orthosilicates is characterized by the increase of the complex anionic potentials and the increase of the compound potential from the perchlorates toward the silicates.

Now the question may arise as to what connection is there between the heats of formation and corresponding compound potentials (reciprocal values).

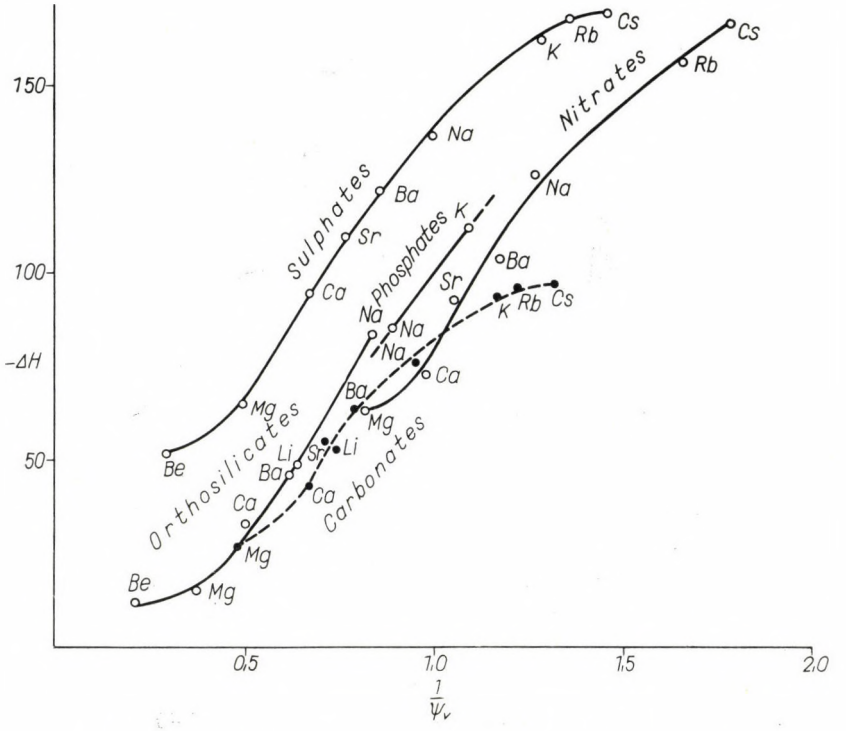

Fig. 4. ΔH of formation vs. compound potential of oxysalts

The heats of formation taken from RAMBERG's work (1952 b) are comprised in Table 3, whereas the $1/\psi$ values are taken from Table 2.

In Fig. 4 the correlation of the heats of formation with the compound potentials is just as evident as in Fig. 2 and 3. Without intending to go into details of Fig. 4, we wish to point out once more that the compound potentials can be accurately calculated from atomic data knowing the coordination num-

Table 3

	Heat of formation kcal/mol				
	M_2CO_3	$2MNO_3$	M_2SO_4	$\frac{2}{3}M_3PO_4$	M_4SiO_4
Li	53.35	89.00	106.15		49.0 ±5
Na	75.99	124.59	137.13	85.22	83.7
K	93.81	150.58	162.56	112.7	87.5 ±7
Rb	96.31	156.18	167.68		
Cs	96.21	160.70	168.85		
	MCO_3	$M(NO_3)_2$	MSO_4		M_2SiO_4
Be	—	—	52.1		12.0 ±5
Mg	27.45	63.11	64.95		15.1 ±1
Ca	43.35	72.97	95.1		32.8 ±0,5
Sr	55.15	93.0	110.6		
Ba	63.45	104.5	122.5		46.0 ± 7

ber of the cations and the 0—0 distances within the complex anion in the compound investigated, whereas the heats of formation are sometimes uncertain as is indeed the case with alkali and alkaline earth silicates.

It is hoped that by pointing out the correlations mentioned above, the purpose of giving a physical interpretation to the compound potentials whose empirical values have proved suitable to interpret geochemical processes, is to some extent approached.

REFERENCES

CARTLEDGE, G. H.: Jour. Phys. Colloid. Chem. **55,** 248, 1951. — GRASSELLY, GY.: Acta Miner. Petr. Univ. Szegediensis, **12,** 31, 1959. — JAZIMIRSKY, K. B.: Thermochemie von Komplex Verbindungen. Akademie Verlag, Berlin, 1956. — RAMBERG, H.: Jour. Chem. Phys. **20,** 1532, 1952a. — RAMBERG, H.: Journ. Geol. **60,** 331, 1952b. — RAMBERG, H.: Amer. Miner. **39,** 256, 1954. — SZÁDECZKY-KARDOSS, E.: Acta Geol. Acad. Sci. Hung. **2,** 285, 1954. — SZÁDECZKY-KARDOSS, E.: Acta Geol. Acad. Sci. Hung. **3,** 115, 1955. — SZÁDECZKY-KARDOSS, E.—GRASSELLY, GY.: Acta Geol. Acad. Sci. Hung. **IX,** 1965.

О НАСТОЯЩЕМ ПОЛОЖЕНИИ РАЗВИТИЯ КОНЦЕПЦИИ ПОТЕНЦИАЛОВ В ГЕОХИМИИ

ДЬ. ГРАССЕЛЛИ

Р е з ю м е

Величины комплексных анионных потенциалов или потенциалов соединений, подсчитываемых из атомных констант, использовались и до сих пор широко для интерпретации геохимических процессов, несмотря на отсутствие термохимических данных. Автор настоящей работы указывает на несколько закономерных зависимостей между величинами вышеупомянутых потенциалов и термохимическими данными, а именно между величинами комплексного анионного потенциала и гидратационного тепла, с одной стороны, и потенциалов соединений и выделяющейся теплоте, с другой. Таким образом, наряду с расширением области применения потенциалов, раскрытие закономерностей позволит додойти ближе к более точной физической интерпретации величин упомянутых потенциалов.

GEOLOGICAL STUDIES IN THE HALIMBA BASIN

By

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The largest bauxite deposit of Hungary overlies Upper Triassic Hauptdolomite and Dachstein limestone. The tectonic contact between these two formations is of pre-Senonian age. Later the region was uplifted and eroded to a peneplain and bauxite was deposited in sinkholes of karst origin. The bauxite grades into terrestrial Upper Cretaceous deposits overlain in their turn by a coal-bearing series and by marine deposits, also of Upper Cretaceous age. In some parts of the area the Upper Cretaceous was subsequently eroded and here the bauxite directly underlies Lower Eocene strata.

On the basis of the data furnished by 700 core drillings, of the chemical analysis of 3400 bauxite samples and of the thorough study of a large number of cores the author arrived at the conclusion that the Halimba deposit is a reworked bauxite. Most cores bear some evidence of reworking and their chemical analyses reveal the ore to be of a low and capriciously variable grade. This is particularly true of the carbonate content, which frequently contaminates the Halimba bauxite.

The limit between bauxite and the overlying terrestrial formation is artificial, rocks having a module (alumina to silica ratio) greater than unity being classed as bauxite. There occur in the bauxite deposit intercalations of lower-than-ore grade bauxite identical in all respects with the overlying terrestrial deposits.

The post-Upper Cretaceous bauxite horizon of Hungary is represented by a few rags overlying the Upper Cretaceous Hippurites limestone.

The intensity of the tectonic movements at the Cretaceous-Eocene boundary is indicated by the intensive faulting of the bauxite, and of its Cretaceous cover as well as by the fact that Upper Cretaceous Hippurites limestone is found in a few isolated downthrown blocks. Further the core material also bears evidence of intense, compressive post-Eocene dislocations.

Thickest and highest-grade bauxite occurs in a band along the contact of the limestone and dolomite of Upper Triassic age, the Triassic rocks here being most intensely faulted and karsted.

The majority of the deposit is found below the karst water table. As shown by the history of the nearby coal mines, the fissured and porous Upper Eocene Limestone, overlying the bauxite, the former ranging in thickness from 60 to 70 metres, may be the source of dangerous floods in the mines. The karst cavities in the Triassic are conveniently plugged with bauxite and clay to render floods from below highly unlikely.

The present paper is based on the study of the core samples and logs of some 700 borings most of which, drilled before 1961, have been cored in their full depth. The manuscript was completed on the 2lst February 1962.

The bauxite of Halimba was discovered in 1920 in a borehole drilled for coal. Investigations pertaining this deposit up to the year 1950 have been summarized by GYÖRGY (1923), VADÁSZ (1935) and VITÁLIS (1932). The results of intensive drilling which was initiated in 1950 as well as the literature dealing with the area were summarized by BARNABÁS (1955, 1957a, b).

The deposit of Halimba situated on the northern margin of the South-western Bakony Mountains is the largest known bauxite deposit in Hungary. It measures 3.5 kilometres north to south and 2.3 kilometres east to west. It constitutes a solitary occurrence measuring 4.6 sq. km in areal extent and is interrupted by 6 small "windows". The bauxite seldom exceeds a thickness of 30 metres. The deposit does not have sharp boundaries (Fig. 1).

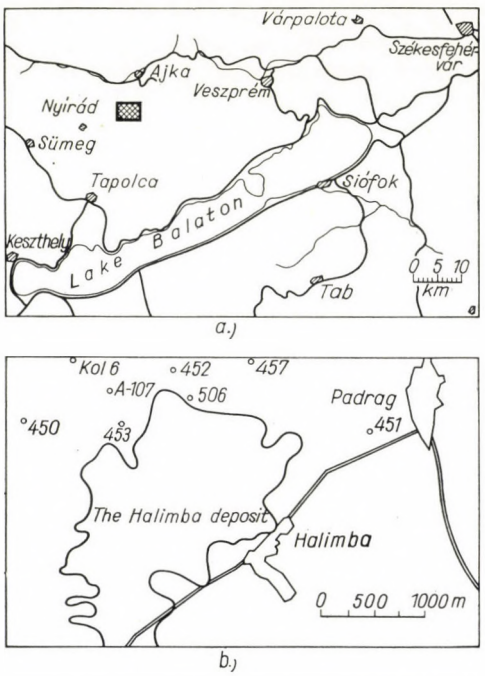


Fig. 1. Sketch map showing the location of the Halimba deposit

The bedrock

a) *Upper Triassic Hauptdolomite* (Figs. 2, 3), the oldest formation encountered in the borings and outcrops in the Halimba region, is, when fresh, a massive rock of saccharoidal structure, locally rather conspicuously stratified. Most of the dolomite cores exhibit a more or less strong brown or yellow tint. Fissures in the dolomite, filled by bauxitic material, are coloured pink or red. Manganiferous dendritic patterns are fairly common on joint surfaces. In places the dolomite is corroded and small cavities are plentiful.

At the surface of the dolomite and in the fissures directly beneath it lemon-yellow clay a few millimetres to 20 centimetres thick frequently separates the dolomite from the bauxite. Plastic and smooth to the touch when wet,

this clay is of a waxy consistency when dry, much resembling the ochre found in the sinkholes of the dolomite at Cserszegtomaj.

The dolomite being thoroughly shattered, it very seldom yields unfissured cores. Its surface is uneven and karsted, and shows depressions and sinkholes.

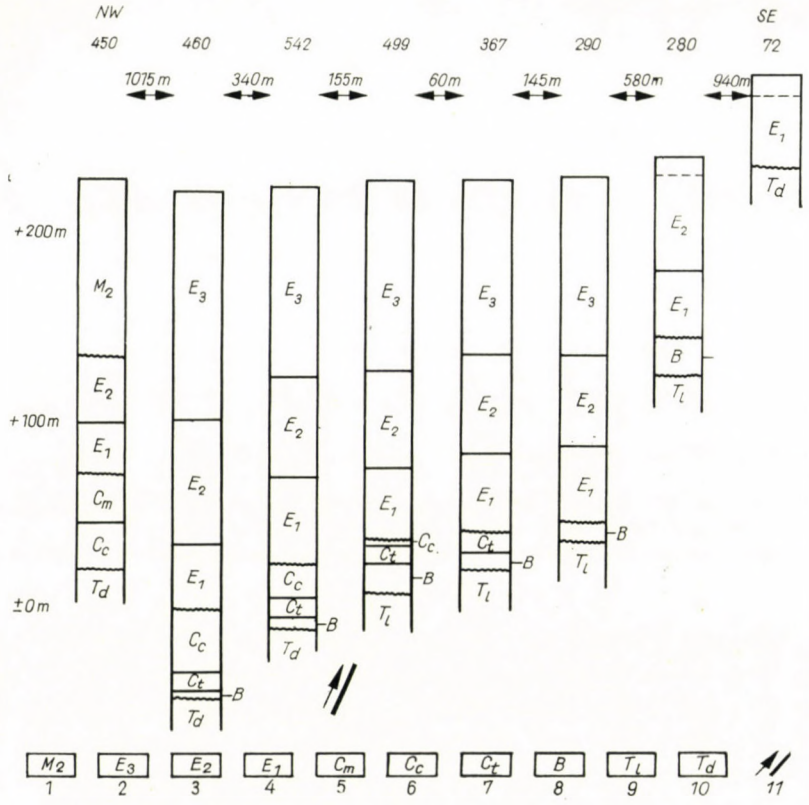


Fig. 2. Typical borehole logs from the Halimba Basin
Legend: 1. Clay, gravel, marl — Middle Miocene, 2. Clay, clay marl — Upper Eocene, 3. Limestone, marly limestone — Middle Eocene, 4. Limestone, limy marl, clay, coaly clay — Lower Eocene, 5. Marine limy marl — Upper Cretaceous, 6. Marl, clay, coaly clay, coal — Upper Cretaceous, 7. Mottled marl and clay, gravel, conglomerate — Upper Cretaceous, 8. Bauxite, clayey bauxite, bauxitic clay — Upper Cretaceous, 9. Dachstein limestone — Upper Triassic, 10. Hauptdolomite — Upper Triassic, 11. Reverse fault

Fractured and densely jointed dolomite is presumably altered to a depth of a few dozen metres. Out of 117 borings reaching the dolomite bedrock, as few as 28 were sunk deeper than 10 metres. Even the deepest drill-hole (35.9 metres) encountered throughout brown- and yellow-spotted fissured dolomite.

Bauxitic clay filling the fissures in the dolomite is also fairly common. In one drilling, dolomite was found to alternate five times with bauxite within

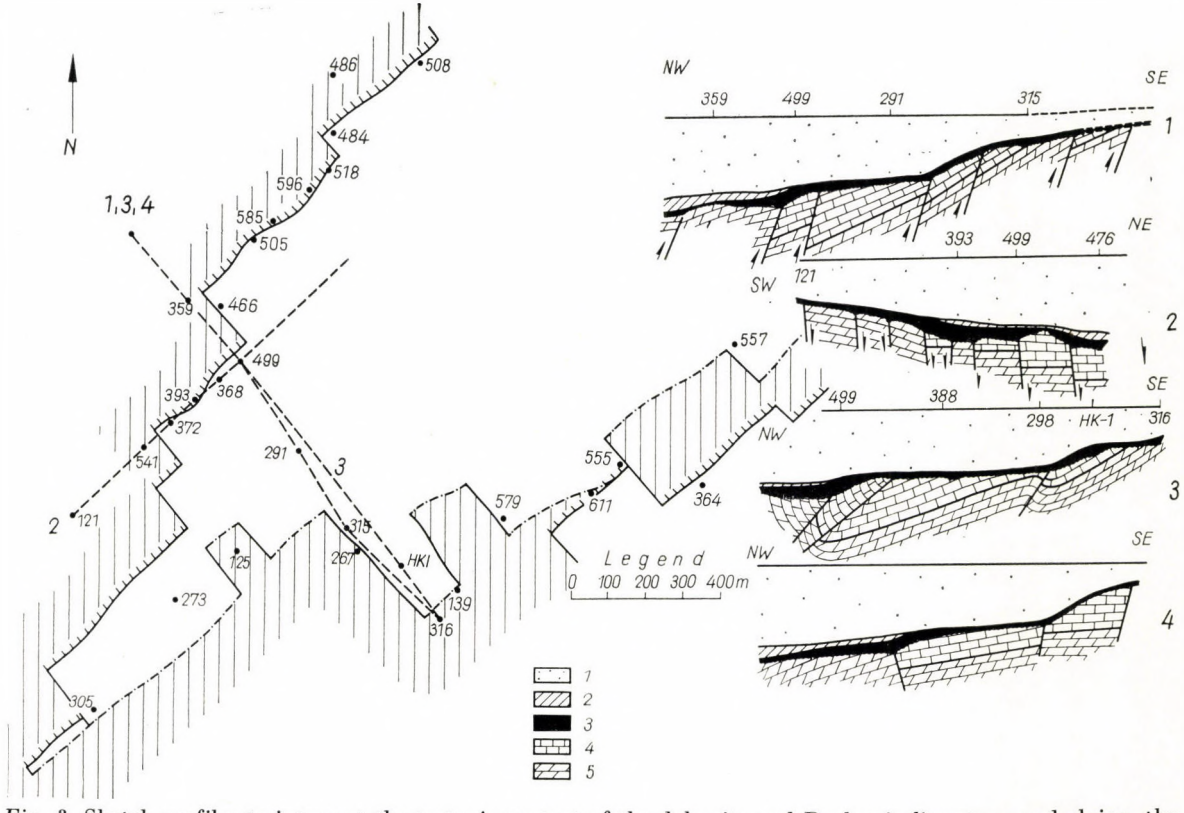


Fig. 3. Sketch profiles to interpret the tectonic contact of the dolomite and Dachstein limestone underlying the bauxite deposit

Legend: 1. Eocene — 2. Upper Cretaceous coal measures — 3. Upper Cretaceous bauxite and terrestrial deposits — 4. Upper Triassic Dachstein limestone — 5. Upper Triassic Hauptdolomite

a depth interval of 15.5 metres. The recovered core was insufficient to ascertain whether this was due to fissures in the dolomite filled with bauxite or to the alternation of bauxite with reworked dolomite.

Exposed for a protracted period of time prior to the deposition of bauxite over it, the dolomite underwent a peculiar kind of karst evolution. Those places where it underlies bauxite the dolomite is of a deeper colour and is more intensely altered than at those places where bauxite is absent.

In open-pit workings one frequently observes a thin hard manganiferous ferruginous crust at the contact of dolomite and bauxite. In the Halimba deposit this crust is mostly absent and the dolomite directly underlying the bauxite is pronouncedly pulverulent.

No fossils indicative of the exact age of the dolomite underlying the bauxite deposit of Halimba were found in the cores. However, the lithologic and stratigraphic analogy with fossil-bearing outcrops elsewhere warrant an Upper Triassic, Noric age. A weighty argument in favour of this age is the presence of a "Koessenian" series including a characteristic Rhetian fauna between the Hauptdolomite and the Dachstein limestone both at Halimba and in the surrounding areas (VÉGH 1961).

The dolomite is of a fairly varied composition. Those parts that were richer in $CaCO_3$ content, underwent a more intense karst evolution prior to bauxite deposition. This type of karst represents a transition towards the true karst developed on the Dachstein limestone.

As to its lithofacies the Hauptdolomite is a precipitate formed in a shallow open sea rather far off the shore. Its total thickness is unknown.

b) White or pinkish, sometimes yellowish, more seldom pale brown, yellow, flesh-coloured or violet, the *Dachstein limestone* is a hard brittle rock of conchoidal to angular fracture and saccharoidal to crystalline structure. It is more coarsely cataclastic and less altered than the dolomite.

The Dachstein limestone is intensely fissured, cracks thinner than one millimetre being most abundant. The fissures generally contain calcite, bauxitic clay, rarely a yellow plastic clay. The fissure planes frequently exhibit manganiferous dendritic patterns. The coloration of the fissure fillings and of the rock adjacent to the fissures, depends on the colour of the overlying deposit.

The fairly high solubility of the limestone, considerably greater than that of the dolomite, resulted in the formation of a typical karst prior to the bauxite deposition. The karst cavities are frequently filled with bauxitic clay to a considerable depth. A boring that penetrated the Dachstein limestone to a depth of 35.5 metres throughout encountered fissures filled with bauxitic clay. The borehole sunk deepest in to the limestone (68.9 metres) traversed intensely brecciated rock up to 50 metres and then fairly friable rock, with a cavity of one metre diameter filled with bauxitic matter at 55 metres depth. Even in the las core (68.9 metres below the top of the limestone) fissures of 0.1 to 2.0 milli-

metres depth filled with a bauxitic substance were fairly abundant. However, this drilling was located near one of the major faults of the area. Also the rest of the 29 borings that penetrated the limestone deeper than 10.0 metres (10.0 to 52.3 metres), furnished proof of intense fissuration, cavernous structure and variegated colour.

The impervious bauxitic clay filling the cracks, fissures and occasional caverns of the Dachstein limestone provides sufficient protection against the waters contained in the Triassic karst reservoir.

In several instances the borings encountered dolomite detritus on top of the Dachstein limestone. In the zone where the bauxite is underlain by Dachstein limestone, only one boring encountered dolomite beneath a thin veneer (17.5 metres) of Dachstein limestone. This dolomite might just as well belong to the Koessen series as to the Hauptdolomite. Also the "calcareous dolomite" encountered in some borings may conceivably represent the Koessen series. As a matter of fact, the lower section of the Dachstein limestone, characterized by the intercalations of dolomite, indicates a gradual transition towards the dolomite sequence (BARNABÁS 1957). The presence of the Koessen strata encountered in a number of places elsewhere in the Bakony Mountains and in the close vicinity of the Halimba basin (namely at Szőc: see VÉGH 1961, BARNABÁS 1957b) was definitely proved by three holes sunk on Somkő-tető Hill four kilometres southeast of Halimba. Of the fossils encountered in

Table I

Analyses of the Triassic

Symbol of boring	H—325			H—314	H—318	H—294
Depth interval	111—114	117—118	118—119		173.4	
Al_2O_3	0.4	—	—	0.2	—	0.8
SiO_2	1.1	1.0	0.2	0.25	0.1	1.3
Fe_2O_3	1.6	3.2	1.8	1.6	0.8	1.2
TiO_2	—	—	—	—	—	—
CaO	31.0	43.0	53.7	43.0	54.0	40.0
MgO	18.0	10.1	tr	9.0	—	11.0
V_2O_5	0.045	0.013	0.001	0.004	0.004	0.011
Cr_2O_3	—	—	—	—	—	—
P_2O_5	0.016	0.030	0.012	0.011	0.030	0.007
MnO_2	1.88	0.68	—	0.68	tr	0.15
Alkalies	—	—	—	0.10	—	0.50
Ign. Loss	43.74	42.8	44.1	44.86	44.2	44.08
CO_2	39.94	39.98	39.91	40.80	31.70	30.20
SO_3	2.14	2.20	2.40	2.10	2.28	2.34

them, Avicula falcata STOPP. and Placunopsis alpina (WINKL.) are characteristic Koessen elements whose life span does not go beyond the Rhetian stage.

The bedrock map (Fig. 3) reveals the contact between the limestone and dolomite to be a zigzag line following the checkerboard pattern of faults characteristic of the Transdanubian Mountains. This contact is most probably a tectonic one. Besides, in most outcrops the contact between these two elements of the Upper Triassic series is likewise tectonic and the concordant superposition of the layers is very rarely seen (VÉGH 1961).

Interpretation of the dislocations that resulted in this zigzag pattern follows below.

a) As a result of one of the phases of orogeny prior to the deposition of bauxite the dolomite may have been overthrust on to the limestone along a fault plane of NE—SW strike of northwest inclination. Similar structural elements are known from a number of places in the Bakony Mountains. Several overthrusts parallel to the one indicated on the bedrock map may be conceived. However, it is impossible to prove them if there is no difference in the constitution of the participating units, that is, if limestone is thrust upon limestone or dolomite upon dolomite. Subsequently, the entire overthrust zone was displaced en echelon by transverse or normal faults and it was in this way that the aforesaid zigzag line came to exist. This latter displacement, older at any rate than the bauxite deposition, might

bedrock of the bauxite

H—564	H—573				H—293	H—345
222.1—233.5	180.2—181.3	181.3—183.3	183.13—185.4	186.4—187.4	194.2—201.7	194.8—200.8
2.3	0.64	0.77	0.64	0.90	0.90	1.02
0.03	0.32	0.10	0.10	0.68	0.0	0.30
0.14	0.12	0.19	0.24	0.14	0.19	0.21
0.03	0.02	0.02	0.03	0.03	0.03	0.03
32.4	53.50	52.34	53.76	45.76	53.70	49.25
15.65	0.36	1.46	1.46	6.70	1.18	3.27
tr	0.004	0.004	0.004	0.004	0.004	0.004
tr	0.005	tr	0.005	tr	0.005	0.005
0.40	0.35	0.17	0.18	0.24	0.14	0.59
—	0.02	0.15	0.23	0.13	0.01	0.0
—	—	—	—	—	—	
47.4	43.65	43.4	43.6	44.0	43.5	44.6 —
—	—	—	—	—	—	—
0.13	0.03	0.07	0.13	0.07	0.10	0.10

have taken place during the same phase of overthrusting. Finally, the entire area was eroded to a peneplain under a tropical climate (Fig. 3, Profile 1).

It has to be emphasized that in transverse faulting even if the strike-slip component of the displacement was predominant, it never was the only displacement. Dislocation patterns due to transverse faulting with some dip-slip component can readily be observed in the thoroughly mapped areas of the Bakony Mountains (TELEGDY-RÓTH 1927).

Another possible interpretation of the zigzag pattern is that the thrust plane, instead of being broken up by transverse faults, was subjected later on to normal faulting that grave rise to a series of horsts and grabens, the fault planes being perpendicular to the strike direction of the thrust plane. This relief was then turned into a peneplain by subsequent large-scale denudation. Under this assumption the lengths of the straight stretches of the zigzag line correspond to the breadth or throw of the individual fault blocks respectively. This interpretation is illustrated by Profile 2 of Fig. 3.

b) The tectonic contact of dolomite and Dachstein limestone may further be interpreted by a combination of folding and faulting (Bruchfaltung) as shown on Profile 3 of Fig. 3.

It has been lately observed in an increasing number of instances in the Bakony Mountains that even in the brittle carbonate rocks older than Barremian fairly regular fold structures can be traced (KOPEK 1961).

The folds whose axes were parallel to the general strike of the Mountains might have broken up at the time of their origin. It is, however, more probable that they were faulted parallel and perpendicular to their strike by subsequent tectonics. The checkerboard pattern of faults thus developed then resulted in an uneven sinking of the individual fault blocks. Movements with a more or less pronounced strike-slip component also occurred.

c) It is not unconceivable that the tectonic contact of limestone and dolomite should have been caused by normal faulting rather than by overthrusting. In this case the Dachstein limestone is supposed to have been preserved in a graben parallel to the strike of the Mountains (Profile 4 of Fig. 3). Perpendicular faults then gave rise to a series of horsts and grabens perpendicular to the above-mentioned first-formed large graben. The faults forming the limits of the individual blocks then appear as the borderline of the limestone against the dolomite.

Each of the above concepts is capable of explaining the facts. There are superficial examples for every one of them in the Bakony Mountains.

The bauxite body

Disclosed in part of the area by mining operations, the bauxite body is fairly well known. It overlies the uneven karsted and peneplaned surface of

Upper Triassic rocks intensely faulted in pre-Senonian times. Between the Upper Triassic and the bauxite deposit one frequently encounters a thin layer of detritus of dolomite or limestone. In one boring a layer of carbonaceous clay 1.6 metre thick was found to underlie the bauxite deposit.

We shall consider as "bauxite" everything that lies between the floor consisting of Triassic limestone and dolomite, including the detritus derived from

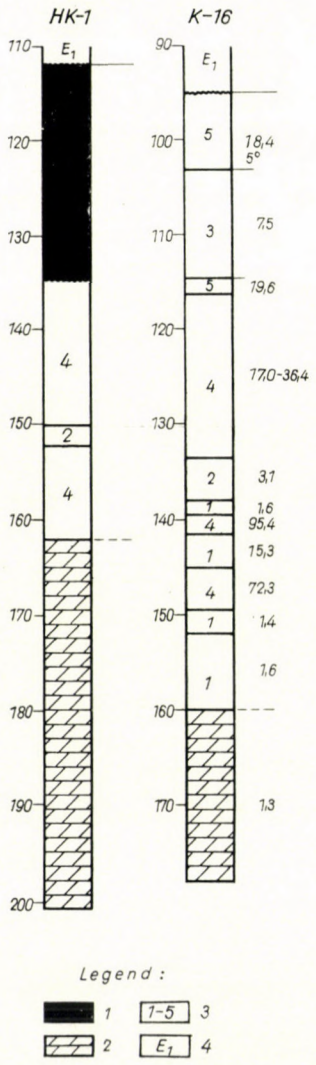


Fig. 4. Borehole logs of the Koessen series

Legend: 1. Bauxite 2. Upper Triassic Hauptdolomite 3. Koessen Horizon of the Upper Triassic: [1] dolomite; [2] calcareous dolomite; [3] dolomitic limestone; [4] limestone; [5] marl, limy marl 4. Lower Eocene undivided. The numbers to the right of the right-hand log indicate the $CaCO_3$—$MgCO_3$ ratio

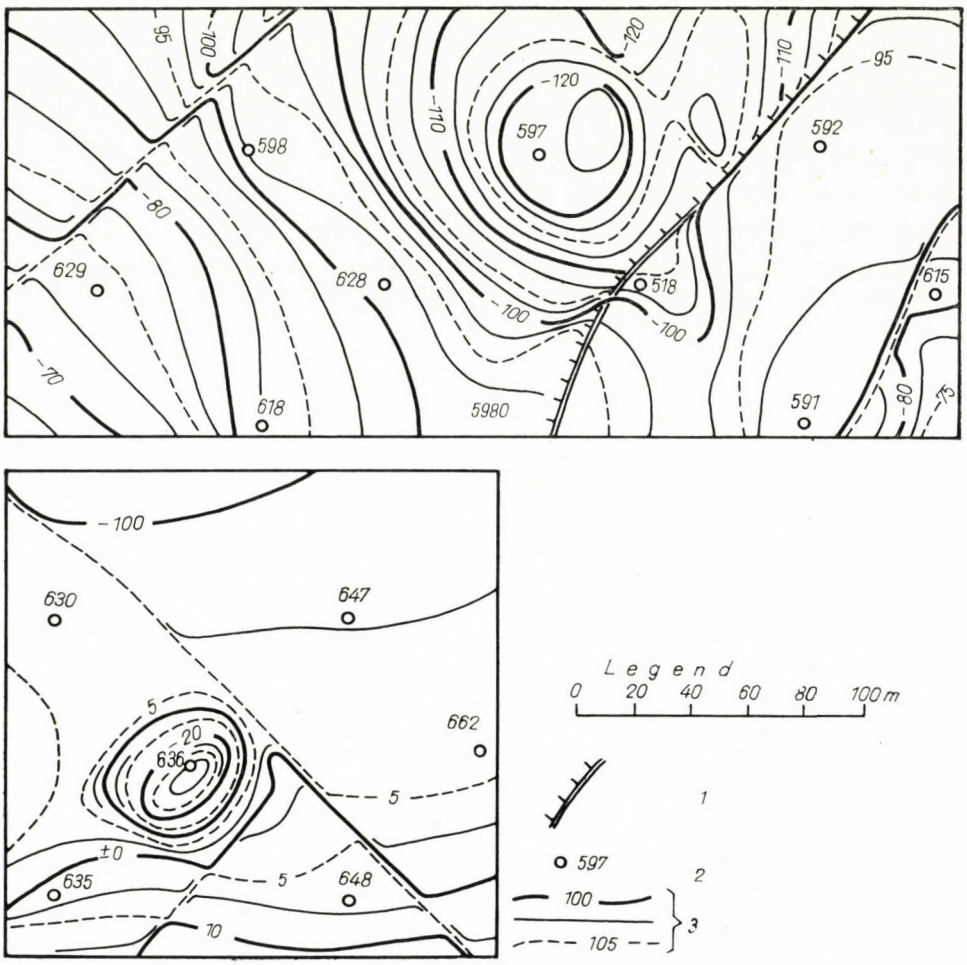


Fig. 5. Details of the relief of the bauxite floor in the Halimba Basin
Legend: 1. Reverse fault (Pre-Upper Cretaceous) — 2. Boring with serial number — 3. Contour lines

these rocks and the roof consisting of Upper Cretaceous terrestrial deposits or the Eocene, irrespectively of whether the material is of a commercial grade or otherwise.

Delimitation is difficult where bauxite grades into the "mottled marl" or "mottled clay" of the Upper Cretaceous terrestrial series. In this case the limit is generally drawn where the module (alumina to silica ratio) of the sediment drops below unity. This distinction, of course, is purely artificial: indeed, within the bauxite body itself, one frequently encounters clayey intercalations whose module is less than unity. It is as a matter of fact

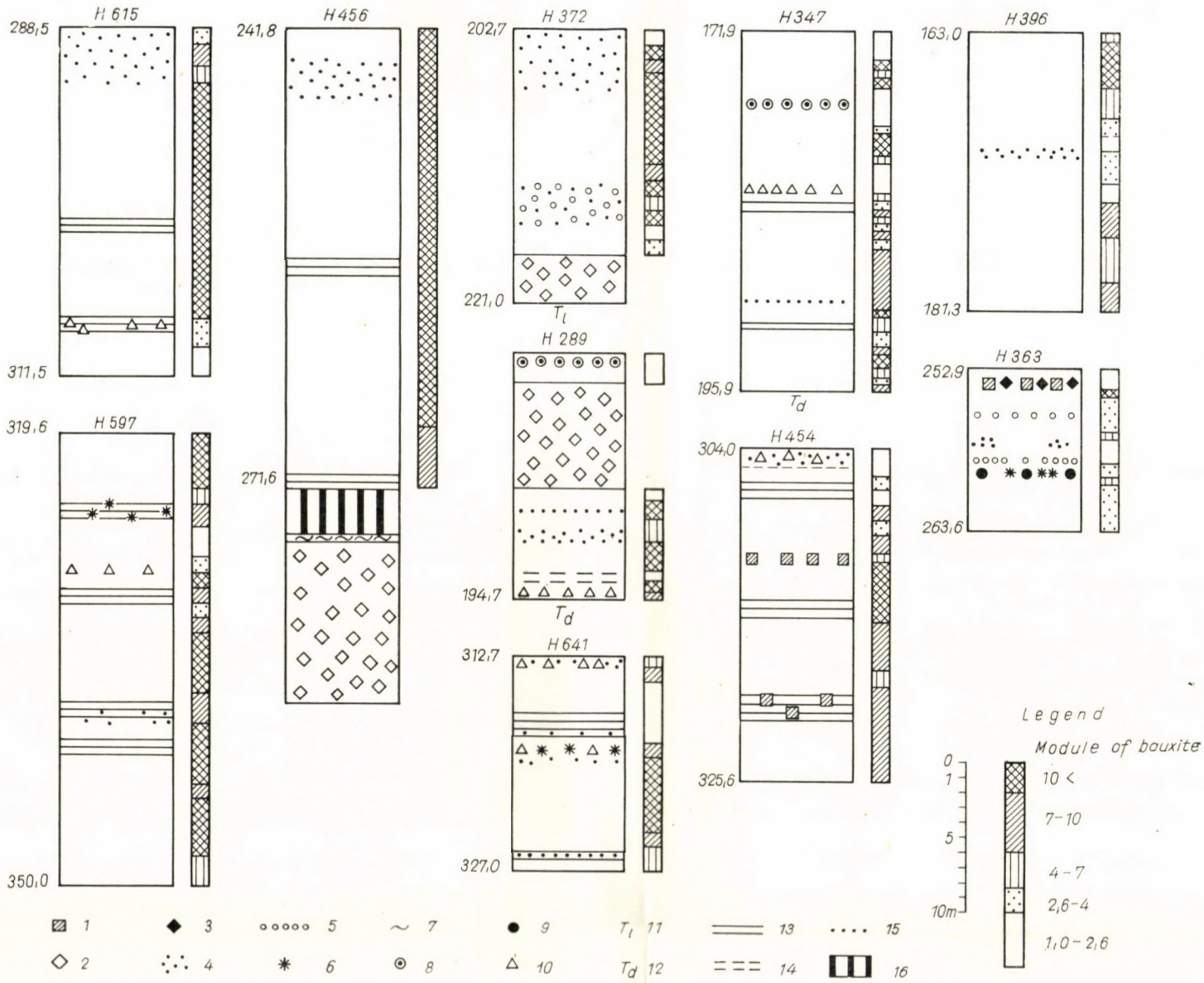


Fig. 6. Bauxite profiles

Legend: 1. Bauxite debris — 2. Dolomite debris — 3. Dachstein limestone debris — 4. Altered pisolites — 5. Oolite — 6. Pyrite nodule — 7. Bauxitic clay — 8. Quartz pebbles — 9. Dachstein limestone pebbles — 10. Clay clod — 11. Tl: Dachstein limestone — 12. Td: Hauptdolomite — 13. Stratified bauxite — 14. Layer of yellow clay — 15. Layer of altered pisolites — 16. Coaly clay

Fig. 7. Structural shetch map

Legend: 1. Pre-Upper Cretaceous reverse fault and overthrust — 2. Pre-Upper Cretaceous dislocation — 3. Limit of Dachstein limestone — 4. Limit of the bauxite deposit — 5. Limit of the Upper Cretaceous terrestrial series — 6. Limit of the Upper Cretaceous coal measures and of their marine cover — 7. Profile line — 8. Structural line — 9. Post-Eocene displacement — 10. Proven post-Eocene dislocation, probable but unproven older dislocation — 11. Displacement between the Cretaceous and Eocene — 12. Pre-upper Cretaceous displacement — 13. Rejuvenated structural line — 14. Cataclastic zone — 15. Borehole — 16. Horizontal bedding

impossible to distinguish visually the bauxite from the mottled clay and marl of the cover.

Both the thickness and the average grade of the deposit vary considerably. The changes are most pronounced above the zone of contact of the Triassic limestone and dolomite, at the intersection of fault lines and in zones where the faults are densest. All these features indicate the intense tectonic control of the karst relief of the bedrock. The surface of the bauxite is more even towards the roof than towards the floor.

From the industrial point of view bauxite having a module higher than 2.6 is considered to be of an industrial grade ore. Clayey bauxite with a module varying from 2.6 to 1.8 and bauxitic clay with a module varying from 1.8 to 1.0 is also considered to belong to the bauxite body if it is contiguous with the same. This classification widely used in the bauxite industry has no geochemical foundation. Indeed, from the geochemical point of view, only the rocks having a module higher than 3.4 should be classed as bauxite. The limits for clayey bauxite should be 3.4 and 1.14, for bauxitic clay, 1.14 and 0.85 respectively (BÁRDOSSY 1961).

Bauxite grade varies very irregularly both in the horizontal and vertical sense. In a general way, however, better grades tend to occur where the deposit is thicker. This is particularly true of the zone of contact between Upper Triassic limestone and dolomite, where the previous cataclasis of the bedrock substantially promoted karstification.

Poor grade is frequently due to higher-than-normal carbonate content in the bauxite. Earlier manuscript reports reveal that calcite was first observed in veins and nodules. From this fact the conclusion was drawn that the contamination of bauxite by calcium carbonate is due to descendant waters. This contamination was greatly aided by the disjunctive tectonism subsequent to bauxite deposition. The faults that broke up the bauxite body opened up ways of circulation for the underground waters.

In the opinion of the present author, however, the higher carbonate content observed particularly in the lower reaches of the bauxite body is due in the first place to contamination by limestone and dolomite debris deposited simultaneously with the bauxite rather than to calcite precipitated later on from the ground water solution.

This observation leads us directly to the most interesting problem connected with the bauxite deposit of Halimba viz. the redeposition of the bauxite.

A considerable volume of evidence suggests that most of the material constituting the Halimba deposit of to-day was deposited in its present position already in the form of bauxite. Most of this bauxite might have been derived from quite nearby sources. The possibility of local redeposition postulated here was also suggested earlier by other workers (BÁRDOSSY 1961, SZÁDECZKY-KARDOSS 1955).

The most important evidence is the presence in the bauxite body of non-syngenetic extraneous bauxite ("bauxite nodules", "bauxite pebbles", "bauxite debris", "bauxite grains", "bauxite inclusions", "ferruginous bauxite pebbles") and of foreign contaminations (detritus, gravel and sand of the underlying rocks, quartz gravel and sand, beds of conglomerate and detritus of variegated composition, strings of weathered pisolites, grey "clay inclusions", pyritic marl fragments, marl clods, nodules of altered pyrite). All these elements occur scattered all over the bauxite body and not exclusively at its bottom or top.

A further proof of redeposition is the frequently observed fine stratification, banding and even cross stratification of bauxite. Bauxite mottled with grey clay has likewise been observed.

In a number of instances traces of redeposition are observed throughout the entire depth of the bauxite section. On the other hand, even in places where the bauxite is 20 to 30 metres thick and of a high grade, one very seldom encounters borehole logs bearing absolutely no traces of redeposition.

In one borehole log nodules of brown coal were described. Mention is also made of a 0.4 metre thick intercalation of coaly clay. In the boring H—456, 29.8 metres of bauxite (!) rest over 1.6 metres thick coaly clay interwoven with 2 to 5 centimetres thick coal seams. This proves that the entire body of bauxite, which is of a considerable thickness, is redeposited.

A further proof of redeposition is furnished by the large number of altered pisolites frequently observed in drill cores throughout their bauxitic section. Weathered nodules, besides occurring scattered or in aggregates, also form strings, layers and lenticles, sometimes even "pisolite conglomerates". Weathered pisolites are mostly rust brown or reddish brown in colour, but "green", "greyish green", yellowish grey and pulverulent types have also been observed. Pisolites in bauxite may undergo alteration such as limonitization or the development of a weathered-looking outer layer due to the action of water circulating along the fissures in the bauxite. However, this phenomenon so often observed in the entire vertical section of the deposit must at least in part necessarily be due to the process of redeposition of the bauxite. This is particularly true if the weathered pisolites are abundant enough to form complete layers (e.g. "pisolite conglomerates").

Frequently observed layerings, the platy, foliated, banded or shaly aspect of the bauxite, is also an argument in favour of redeposition. Layering is due to some foreign material, mostly clay, interbedded in the bauxite series. Pale yellow bands of calcareous clay, layers of greyish brown clay, grey clay, etc. have also been observed. In one core a pale yellow calcareous clay layer was found to contain a pisolite consisting of limonite.

Occasional oolitic layers in bauxite, as well as the pyritic nodules and grains of pyrite may be interpreted as proof of a stagnant body of water.

Pyrite nodules are particularly abundant in the upper parts of the bauxite. Pyrite and oolites are much more abundant in the superincumbent terrestrial layers.

Some 3500 chemical analyses of the Halimba bauxite permitted the author to study and evaluate in detail the calcium carbonate content of the ore, the latter being of considerable importance from the technological as well as from the economical point of view. Generally an extremely high carbonate content usually goes hand in hand with abundant evidence of redeposition. A further concomitant phenomenon is the highly capricious variation of ore grade.

It is unnecessary to treat here the petrographic and geochemical features of the Halimba bauxite as these have lately been described in detail in a treatise (SZÁDECZKY-KARDOSS 1955) and in a monograph (BÁRDOSSY 1961) respectively.

The bauxite cores reveal an intense structural deformation. The cores frequently have a kneaded appearance not due to drilling. Gleaming slip surfaces, some of them being parallel to the stratification, are fairly frequent. Dips as high as 45° have been recorded in stratified bauxite.

In the Halimba deposit, grey sulfurous bauxite is invariably absent in the areas where the immediate cover is of Cretaceous rocks. In this respect the present author agrees with the hypothesis (BÁRDOSSY 1961a) that grey sulfurous bauxite is of secondary origin being influenced by the superincumbent lower Eocene coal formation.

The cover of the bauxite

The Upper Cretaceous terrestrial series slightly overlaps the bauxite in a northwesterly direction (Fig. 7). In the southwest, it gradually thins out as a result of post-Cretaceous erosion. Its practical importance is restricted to the areas where in the absence of the coal measures it is the only impervious layer between bauxite and the Lower and Middle Eocene limestone and calcareous marl, not taking into account the sporadic, thin Lower Eocene coaly clay.

The terrestrial series is invariably rather intimately connected with bauxite, presenting problems of delimitation where the terrestrial deposits are not sufficiently coarse-grained.

Most of the terrestrial series consists of clayey deposits resembling bauxite such as "mottled clay", "mottled marl". Its coloration is more variegated than even that of some of the most vivid bauxites. It contains more abundant detritus derived from the dolomite and limestone bedrock. Consequently, also its Ca and Mg carbonate content is higher than that of bauxite. It is frequently pyritic.

Most of the features of reworked bauxite are characteristic, even to a considerably enhanced degree, also of the terrestrial Cretaceous. The variegated detritus present in it frequently forms thick lenticles, ill-consolidated breccias and conglomerates of a bauxitic-clayey cement. These layers can be traced with minor interruptions from one borehole to the next over several hundred metres.

The transition of the terrestrial series into the overlying coal measures is often fairly gradual. Its topmost part then consists of a grey clay or marl, representing the bottom of the ancient marsh.

The detritus most abundant in the terrestrial deposit is dolomite. It is present in all samples that contain any detritus. Dachstein limestone detritus is substantially less abundant. Quartz is encountered in the form of sand containing some fine gravel. Independent layers of micaceous, stratified sandstone of calcareous cement are extremely rare. In some instances, however, they were found to directly overlie bauxite, in thicknesses varying from 1.5 to 3.9 m. Otherwise quartz detritus is mostly restricted to the top part of the terrestrial series. The quartz sand of the bauxite and of the superincumbent horizons as well as the black chert observed in the layers of dolomite detritus might have been derived from the middle Cretaceous eroded from nearby areas or from other older deposits.

Pisolites are quite frequent, sometimes forming pisolitic conglomerates 40 to 60 centimetres thick. Bauxite detritus ("bauxite pebbles", "bauxite nodules") is also fairly frequent but it was nowhere observed to form independent layers. Layers of bog ore and oolitic limestone occur very rarely.

Pyrite is fairly widespread in minor quantities. It is mostly disseminated but a few larger nodules have also been encountered. Pyrite sometimes coats the rock fragments in breccias.

Limonitic nodules are fairly scarce.

Calcite crusts and coatings mostly occur in fissures, detritic lenticles and on the surfaces of pebbles. Detritus almost invariably bears a thin coating of calcite, and the same holds true for the pisolites, too.

Stratification and foliation is rare in the terrestrial series. Sometimes cross stratification is observed.

There occur in places intercalations of bauxite of marginal and even industrial grade in the terrestrial series. In the Halimba basin, bauxite and the terrestrial deposits are closely related.

Pollen analysis revealed the Upper Cretaceous emergence in the Southern Bakony Mountains to have lasted till the upper Santonian substage (Góczán 1961).

The Upper Cretaceous coal measures are with a few minor exceptions fairly sharply delimited against the underlying terrestrial deposits. They

represent the continuation of the beds of the nearby Ajka coalfield whose age was established as Senonian by earlier (RAKUSZ 1928) and recent workers (DARÁNYI 1957, GÓCZÁN 1961, KOPEK 1961).

The Upper Cretaceous Hippurites limestone was also encountered in several boreholes, mostly in downthrown blocks. The boring H—491 traversed

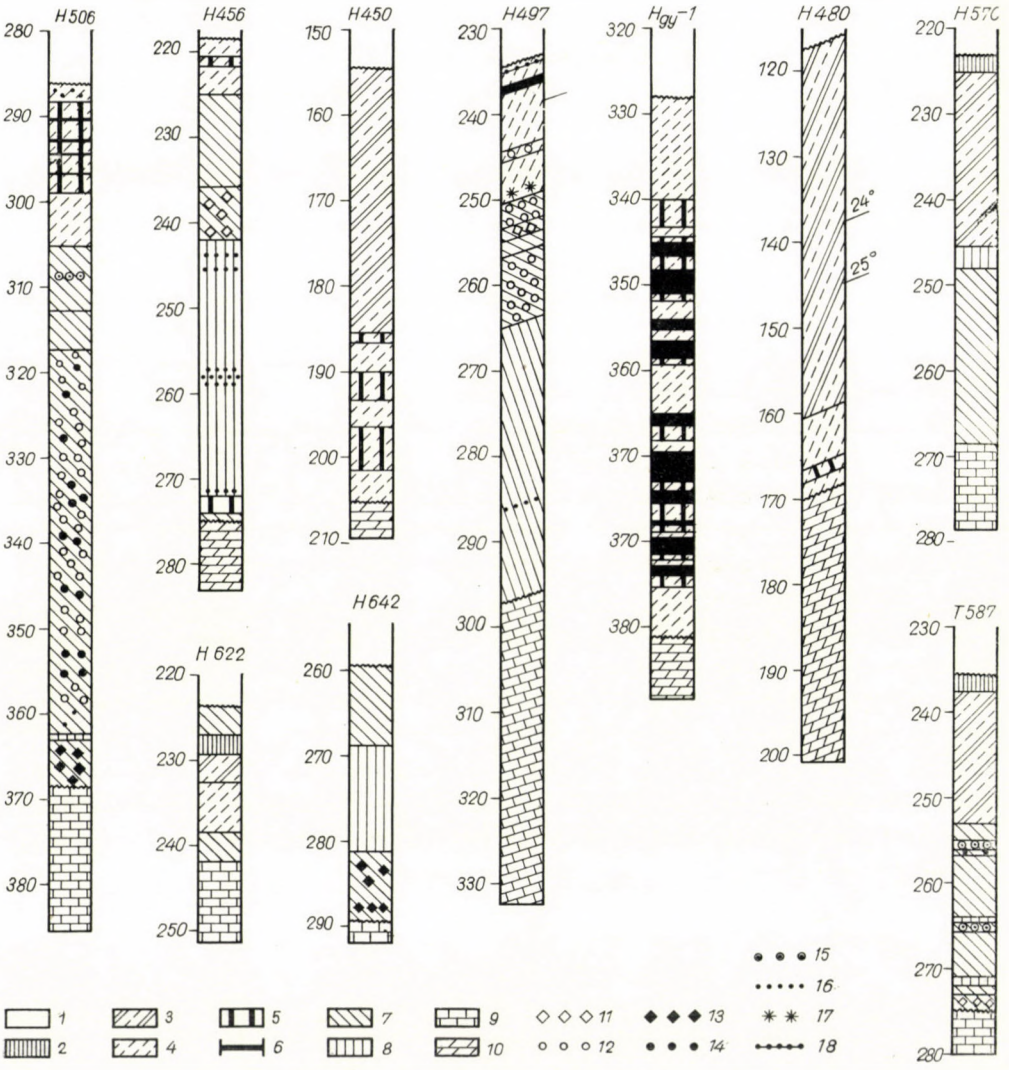


Fig. 8. Upper Cretaceous borehole logs

Legend: 1. Lower Eocene undivided — 2. Reworked bauxite on top of Hippurites limestone; Upper Cretaceous — 3. Hippurites limestone — 4. Limy marl, clay marl, marl, clay — 5. Coaly clay, coaly marl — 6. Coal seam — 7. Upper Cretaceous terrestrial deposits — 8. Bauxite — 9. Upper Triassic Dachstein limestone — 10. Upper Triassic Hauptdolomite — 11. Dolomite debris — 12. Dolomite pebbles — 13. Dachstein limestone debris — 13. Dachstein limestone pebbles — 15. Quartz gravel — 16. Weathered pisolites — 17. Pyrite — 18. Pisolite conglomerate

for a length of 147 metres the Hippurites limestone and a marine calcareous marl, still not reaching the underlying formation. Hippurites limestone and an underlying marine marl have also been encountered to the northwest of the bauxite deposit.

The present extent of the coal measures in the Halimba basin indicates the tectonic control of their erosion and preservation, similar to that of the underlying terrestrial series.

In three borings the Sümeg bauxite level was encountered in the form of bauxite overlying the uneven surface of the Hippurites limestone.

Eocene

The Eocene unconformably overlies the bauxite deposit, the Upper Cretaceous terrestrial series, the coal measures, the Hippurites limestone and even the Triassic limestone and dolomite. The basal formation of the Eocene consists of some thin beds of mollusc-bearing limnic or brackish clay besides a brackish calcareous marl bearing Miliolina and debris of coal, with intercalated lenticles of the above-mentioned clay.

The middle Eocene is represented by the "main Nummulites limestone," 50 to 65 metres thick, grading upwards into 10 to 20 metres of Nummulites marl. The series is highly porous and densely fractured. Most of it is situated under the karst water table. It holds considerable amounts of water that, when struck by mining operations, may drain very fast into the galleries, as experienced in the coal mine at Padrag.

The middle Eocene passes rather gradually into the Upper Eocene calcareous marl. The limit of the Upper Eocene is drawn where the deposit becomes abundantly tuffaceous with layers of tuffitic marl, tuffaceous sand and ill-compacted sandstone. Above the central part of the bauxite deposit, tuffaceous material is not very abundant, but further NNW it is considerably enriched and 1.5 kilometre north of the limit of the deposit the tuffaceous horizon is as much as 20 metres thick. Petrographic examination of the tuff encountered in several borings of Halimba, reveals it to be an amphibole andesite (Székу-Fux—Barabás 1953).

Disregarding the somewhat harder marl of the lowermost, transitional beds, as well as the tuffitic ingredients, abundant in the lower part of the series, the Upper Eocene series consists of a remarkably uniform clay marl.

The Upper Eocene series is incomplete. It is most fully represented in the NNW region.

Pleistocene

The eroded and weathered surface of the Eocene is overlain by spots and rags of thin Pleistocene deposits (two metres at most).

The congeliturbation of the Pleistocene relief is proved by the fact that the Pleistocene gravelly sand frequently penetrates as wedges and bags into the upper weathered portion of the underlying deposit.

Structural relations

Earlier literature does not treat the structure of the Halimba area. Detailed structure was known but in a few small spots and this was generally insufficient to form a valid picture of the history of mountain building.

A detailed study of the available evidence revealed the following:

a) The dip of the strata very seldom exceeds 25°. In adjacent borings the dip of a given formation may be widely different. Dips observed in the Eocene are slightly more than half the dip of the underlying Cretaceous.

b) Almost every boring furnished some cores traversed by parting planes (slip planes). In the Eocene, swarms of parallel slip surfaces and a few complementary perpendicular ones have sometimes been observed throughout depth intervals of several metres.

The dip of the slip planes is either very steep, 80° to vertical, or gentler, between 40 and 25°. Part of the latter are slips along the bedding planes. Bedding-plane slips at a few degrees of dip or in the horizontal plane have also been encountered.

For the tracing of the vertical displacements undergone by the deposits, the surface of the Triassic is little suited as this karsted peneplain was highly uneven to begin with. The top of the bauxite deposit, an artificially delimited surface, is not of much use, either. The surfaces best suited are the bottom of the Upper Cretaceous coal measures on the one hand and the bottom of the Lower Eocene on the other. Both series being deposited in the vicinity of a flat seashore, their surfaces are most likely to have originally been nearly horizontal.

Besides constructing a large number of profiles, in order to gain a three-dimensional insight into the structure of an area, the present author also employed the less time-consuming method of determining the angle of inclination of a given surface (in the present case, the bottom of the Cretaceous coal measures and of the Lower Eocene, respectively) as available from a set of borings and then writing the value obtained beside an arrow directed towards the boring in which the surface in question is deeper. In this manner some bands and lines were shown up, in which the inclination of the surface was substantially higher than over the region as a whole. The method mostly yielded structural elements parallel to the well-known NE to SW strike of the Transdanubian Mountains, but some divergent E—W and N—S striking ones as well.

Also, the surface mapping of the middle Eocene limestone south and west of Halimba showed up a fairly large number of N—W faults and joints. South of the village of Halimba, in the Malom valley, a fault of 175—355° strike can be traced throughout several hundred metres.

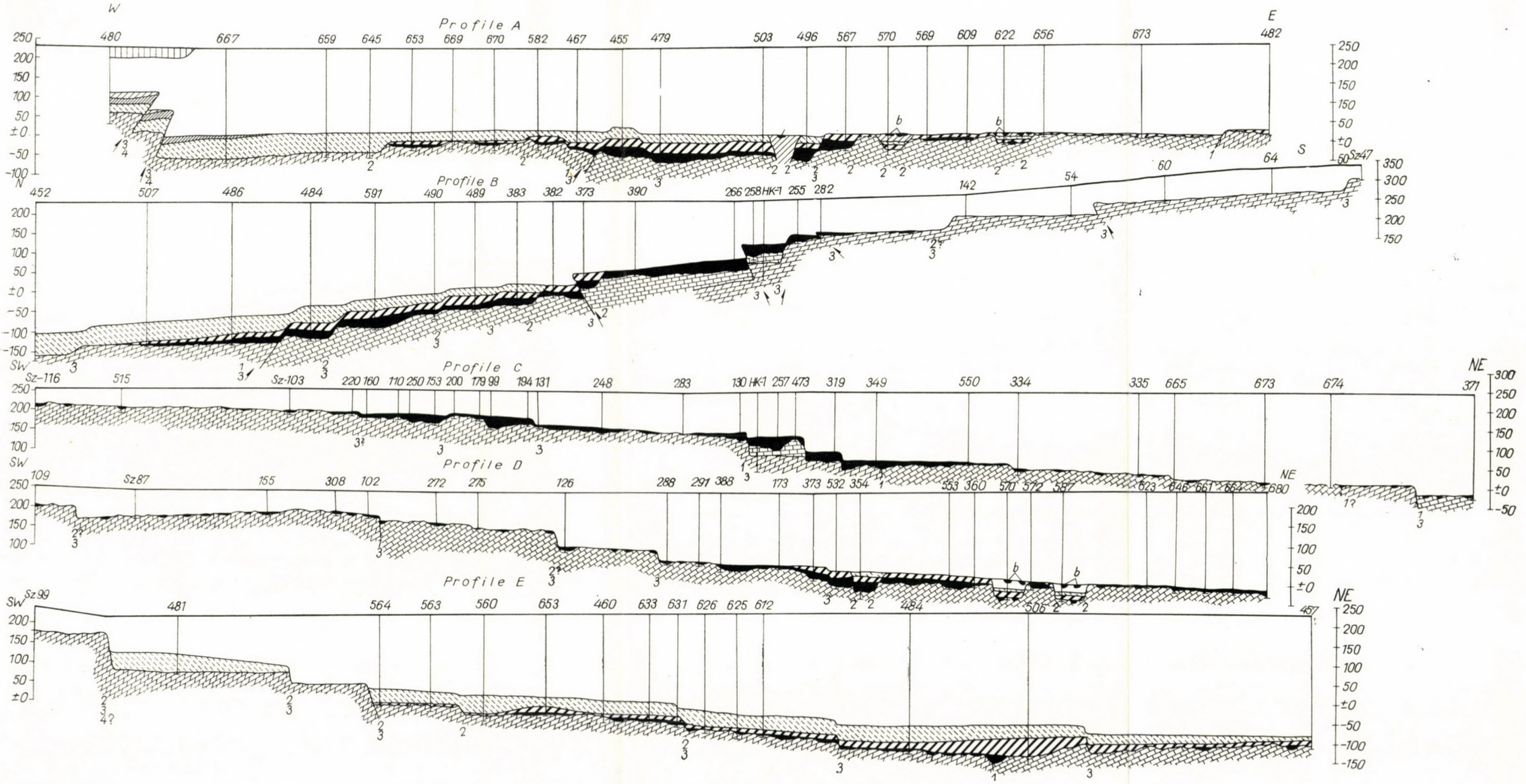
As to the style of the movements, it is not justified to assume fold structures except perhaps in the deposits older than the bauxite.

In the author's opinion, compression and distension played about equal roles in shaping the structures of the Halimba basin. It is very seldom that one finds, in bore-hole logs, clear-cut evidence of compressive tectonics. Nevertheless, in the Halimba area in several instances it was possible to infer structures of this type. Moreover, in two borings the compression indisputably proved to be post-Eocene. According to BALKAY (1960) the Austrian, Savian and Attican phases of STILLE's tectonohistoric pattern were characterized in Hungary by compression whereas the Laramian, Pyrenean and Styrian phases mostly resulted in distension. Thus the post-Eocene compression is presumably to be attributed to the Savian phase. On the other hand, in the spell of emergence between the Cretaceous and the Eocene, distension was dominant. In the Laramian phase, covering this interval, some of the slabs covered by Upper Cretaceous Hippurites limestone and marine marl might have sunk very deep. This is probably why a boring penetrating these deposits to a depth of 147 metres did not reach the bottom of the series. This tectonic pattern may be responsible also for the fact that the Upper Cretaceous survived in but a few isolated rags the early Eocene period of erosion. Also in the nearby Ajka basin the Laramian phase brought about intense faulting and a distension of up to 4 per cent (KOPEK 1961).

In the Halimba area, the fixing of the age of the individual phases of displacement is not always possible to any degree of accuracy.

a) The tectonic contact of the Triassic limestone with the dolomite is presumably due to the Austrian phase. According to recent literature, in the East Alps, Western Carpathians and in Hungary, movements preceding the Austrian phase were largely epeirogenic. In Hungary the most intense deformation took place in the Upper Cretaceous. The main phase of tectonism preceded the Gosau stage of the Upper Cretaceous. In the author's opinion it was this pre-Gosau phase that resulted in the emergence of the Triassic and brought about its erosion. However, the overthrust and perhaps the folded structure supposed by the author for the Triassic is presumably due to the Austrian phase.

b) It is the age of the movement between the Cretaceous and the Eocene that can be fixed most accurately. Besides the unconformity between the Upper Cretaceous and the Lower Eocene Ypresian deposits and the dip angles of the Cretaceous strata amounting to about twice the Eocene dips, the Laramian phase is also proved in a number of instances in the close and broader vicinity of the area (DARÁNYI 1957, KOPEK 1961).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Profile B
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200 150 100 50 ±0 -50 -100 -150
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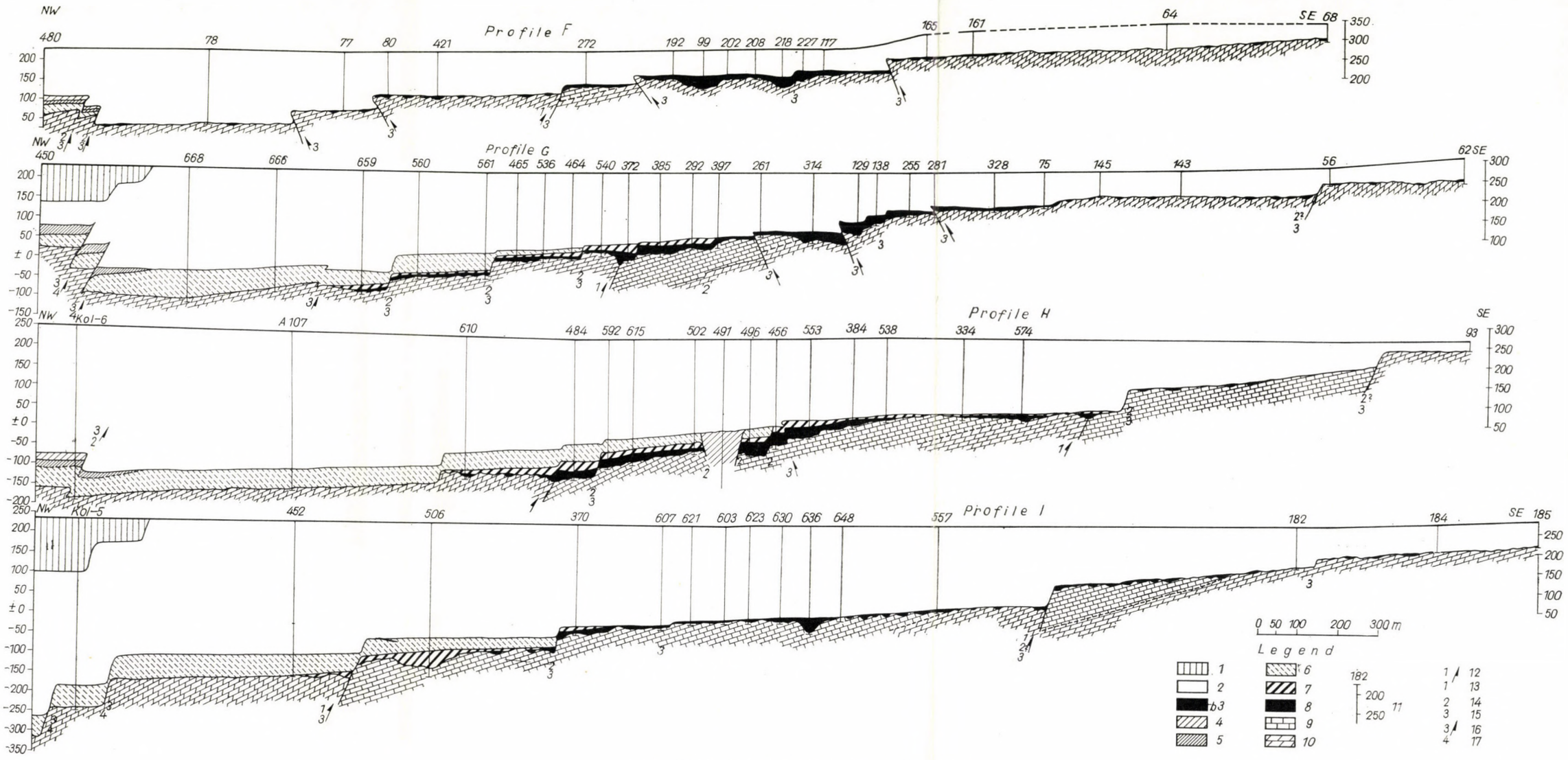

Fig. 11. Geological profiles of the Halimba Basin

Legend: 1. Middle Miocene — 2. Eocene undivided — 3. Upper Cretaceous bauxite on top of Hippurites limestone — 4. Hippurites limestone, Upper Cretaceous — 5. Marine marl, Upper Cretaceous — 6. Coal measures, Upper Cretaceous — 7. Terrestrial deposits, Upper Cretaceous — 8. Bauxite, Upper Cretaceous — 9. Upper Triassic Dachstein limestone — 10. Upper Triassic Hauptdolomite — 11. Borehole with serial number — 12. Pre-Upper Cretaceous reverse fault or overthrust — 13. Pre-Upper Cretaceous normal fault — 14. Dislocation between the Eocene and the Cretaceous — 15. Post-Eocene dislocation — 16. Post-Eocene upthrust — 17. Post-Miocene disclocation

c) It is impossible to fix the age of the post-Eocene movements, the Miocene being restricted to the area N and NW of the Halimba bauxite deposit.

The dip of the bauxite deposit is steepest in the N—S direction. It is, however, not uniform, amounting to 2 to 4 times the average in several subparallel bands of E—W strike. It is in these bands that the Eocene as well as

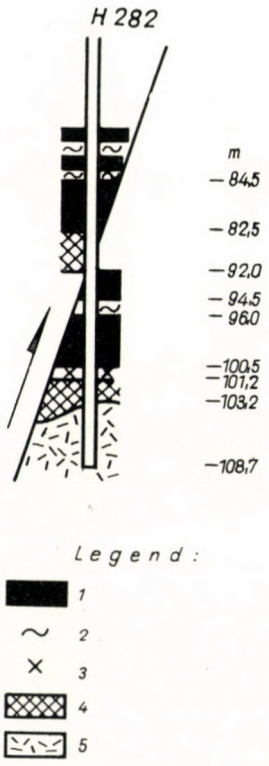

Fig. 9. Borehole log of a reverse fault
Legend: 1. Lower Eocene coaly clay — 2. Lower Eocene Milioline marl — 3. No sample — 4. Bauxite — 5. Upper Triassic Hauptdolomite

the bauxite yielded largely cataclastic, shattered drill cores. This circumstance proves an intense post-Eocene movement, some of which at least was compressive in nature as proved by the repetition of strata in two boreholes of which mention has already been made.

The younger structural lines of E—W and N—S strike presumably reflect the rejuvenation of very old structural elements, as implied by an increasing volume of evidence collected all over the country (Szalai 1960).

The rejuvenation of ancient planes of displacement is, as a matter of fact, observed in a fairly large number of instances both in the case of reverse

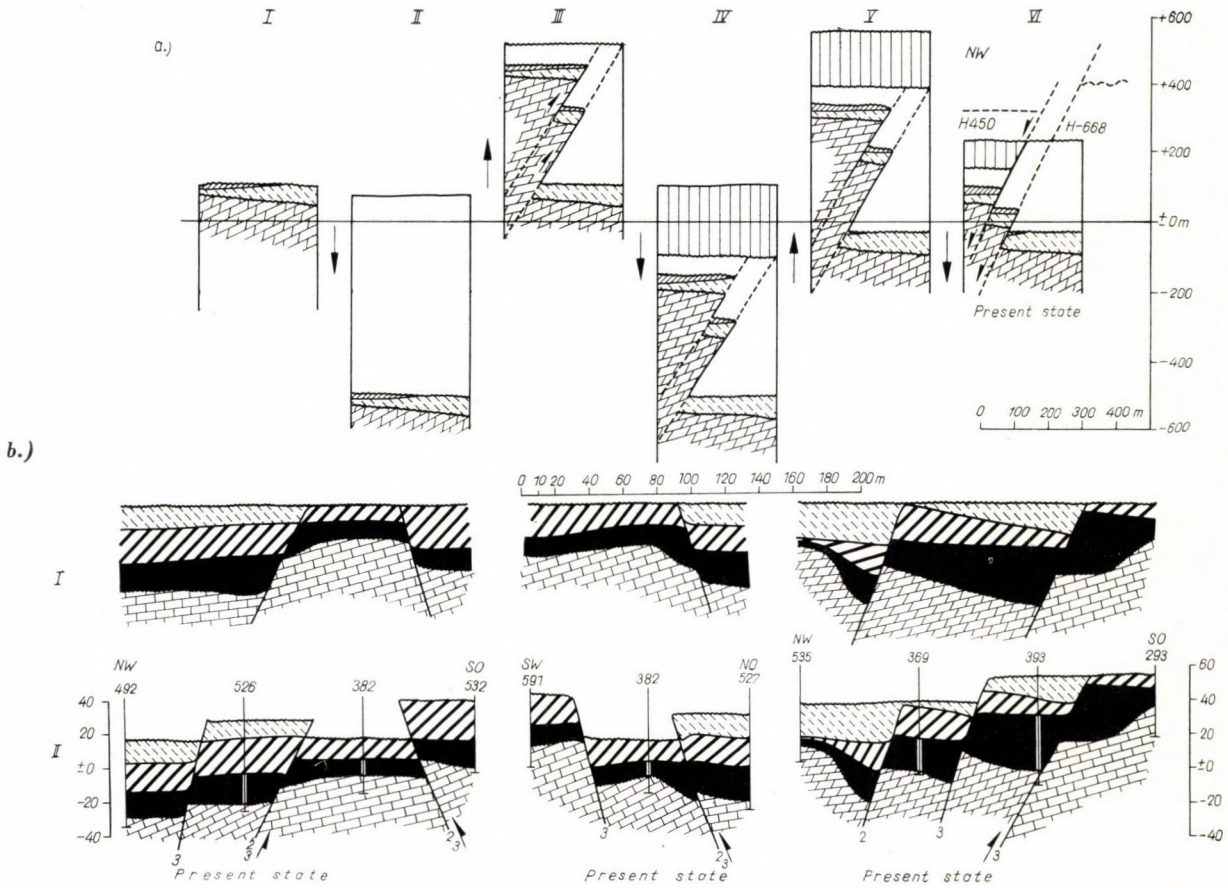

Fig. 12. Typical profiles. For legend see Fig. 11. — *a)* Detailed evolution of the northwest end of Profile G (Fig. 10) — *b)* Typical minor profiles

faults and overthrusts and of strike-slip displacements (DARÁNYI 1957, KOPEK 1961). Unfortunately, in the Halimba area the uneven relief of the Triassic, the small throw of the displacements as compared to the borehole spacing, and other factors, make it very difficult to prove the rejuvenation of the faults.

As to the influence of palaeogeography and structure on mining and ore grade, the rejuvenation of ancient fault planes sometimes resulted in open fractures in the cover of the bauxite. Along these fractures the water contained in the porous overlying deposits may penetrate into the mine, thus presenting a grave danger in the parts of the deposit situated below the water table. Floods from below are much less liable to occur as the caverns and pores of the underlying karsted rocks are filled with bauxitic clay to the point of being more or less impervious. However, younger distensions may have resulted in the opening up of ancient fault lines which subsequently were not sufficiently filled.

The origin of the bauxite

Although it is far from being fully proved in every instance, we may accept the hypothesis that bauxite is a terrestrial deposit contemporaneous with diverse horizons of the Upper Cretaceous marine series. (FÜLÖP 1961.)

Observations prove most of the Halimba bauxite to be reworked. Bauxite in the lower portion of the deposit may be presumed to be unreworked where the drill cores reveal no trace of reworking, grade is uniformly high and the $CaCO_3$ content is uniformly low. It is, however, impossible to distinguish between reworked and unreworked bauxite on the basis of drill cores alone.

Let us consider now in detail the possible age relations of the bauxite.

1. The lower portion of the bauxite may be unreworked older (Lower Cretaceous) bauxite. It may represent a vestige of a considerably thick ancient deposit, preserved in the sinkholes and depressions of the Triassic surface. The preservation of part of this older bauxite then suggests that some of it was covered for some period during the Middle Cretaceous. This case, without being impossible, is far from likely. The only argument in its favour is a rag of the Barremian bauxite horizon beneath Middle Cretaceous layers traversed by one of the coal borings in the Ajka basin (DARÁNYI 1957).

2. A further possibility is that the entire Halimba deposit consists of reworked bauxite but that the deepest, highest-grade parts represent the products of reworking of the best, highest-grade portions of the original deposit, little or not at all contaminated in the course of redeposition. In this case, too, the preservation of Lower Cretaceous bauxite implies that there existed a Middle Cretaceous cover that was not eroded until rather late.

3. In the opinion of the present author, the deposit is fully reworked even if traces of reworking are not ubiquitous. The substance constituting the deposit was consequently a bauxite already at the time of its arrival at the present site, presumably from a nearby deposit to the southeast, formed on a flat karst surface in the Upper Cretaceous (late Turonian to early Senonian). The clayey raw material of this bauxite presumably arrived from one of the outcrops of the crystalline basement (to the NW or to the SSW or both), already in a partially desilicified state. However, some of the clayey products of weathering of the Middle Cretaceous deposits eroded from nearby areas might also have contributed to the raw material of the bauxite. If we accept that the bauxite was formed during the Turonian to lower Senonian phase of emergence, then it was subsequently redeposited as a result of the continuing tilting and erosion of the area of its origin in a depression close to the sea level, on top of a relief that somewhat earlier was a higher karst surface. The upward deterioration of the bauxite deposit of Halimba, the upward increase of the abundance of signs of redeposition, the growing frequency of intercalations of detritus from the underlying deposits indicates that in the course of redeposition, the reworked bauxite was mixed in an increasing proportion with foreign material, that is, the original deposit was being removed by erosion. The bauxite was then soon covered with the Upper Cretaceous terrestrial deposits and with the longshore marsh and swamp deposits and later on, with the marine formations of the transgressing Upper Cretaceous sea. This process, if proved, will presumably turn out to have taken place in the early Senonian.

That part of the bauxite deposit which is not covered by Upper Cretaceous sediments to-day could only stay in place if it was still covered at the time of the Upper Cretaceous subsidence. After a brief uncovered spell at the end of the Cretaceous, it was again soon covered by the Lower Eocene deposits.

The top part of the bauxite lacking a Cretaceous cover yielded a few fossils, fresh-water and brack-water gastropods, that also occur in the fauna of the Ajka coal measures. Also the pollen content of the top part of the bauxite supports an Upper Cretaceous age (H. DEÁK 1960).

REFERENCES

1. AJTAY, Z.: Bányászati és Kohászati Lapok **LXXIV,** 12, 1941. — 2. ANDRUSOV, D.: Geologische Rundschau **50,** 404, 1960. — 3. BALKAY, B.: Geologische Rundschau **50,** 396, 1960. — 4. BARNABÁS, K.: Bányászati Lapok **10,** 455, 1955. — 5. BARNABÁS, K.: Földtani Intézet Évkönyve **XLVI,** 3, 1957. — 6. BARNABÁS, K.: Földtani Intézet Évkönyve **XLVI,** 3, 1957. — 7. BÁRDOSSY, GY.: Földtani Intézet Évkönyve **XLVI,** 3, 1957. — 8. BÁRDOSSY, GY.: A magyar bauxit geokémiai vizsgálata. Földtani Intézet alkalmi kiadványa, 1961. — 9. BÁRDOSSY, GY.: Bányászati Lapok **7,** 457, 1961. — 10. BÖCKH, J.: Mitteilungen aus dem Jahrbuche der Kön. Ung. Geologischen Anstalt, Pesth, **III,** 1874. — 11. DARÁNYI, F.: Bányászati Lapok **12,** 253, 1957. — 12. DARÁNYI, F.: Bányászati Lapok **5,** 310, 1960. — 13. H. DEÁK, M.: Földtani Közlöny **XC,** 125, 1960. — 14. FÜLÖP, J.: Földtani Intézet Évkönyve **XLIX,** 577, 1961. — 15. FÖLDVÁRI, A.: Földtani Közlöny **LXIII,** 97, 1933. — 16. GÓCZÁN, F.: Földtani Intézet Évkönyve **XLIX,** 635, 1961. — 17. GYÖRGY, A.: Bányászati és Kohászati Lapok **LVI,**

2, 3, 4. vol. 1923. — 18. Kopek, G.: Földtani Közlöny **XCI,** 413, 1961. — 19. Köpper, H.: Geologische Rundschau **50,** 457, 1960. — 20. Lóczy, L.: sen.: A Balaton környékének geológiai képződményei. A Balaton Tudományos Tanulmányozásának eredményei. I. 1. — 21. Oravecz, J.—Végh-Neubrandt, E.: Földtani Közlöny **XCI,** 173, 1961. — 22. Ottlik, P.: Földtani Közlöny **LXXXIX,** 174, 1959. — 23. Rakusz, Gy.: M. Királyi Földtani Intézet Évi Jelentése 1925—28-ról. 127, 1935. — 24. Schmidt E. R.: Állami Földtani Intézet Évkönyve **XLIX,** 747, 1961. — 25. Szádeczky-Kardoss, E.: Geokémia. Akad. Kiadó, Budapest, 1955. — 26. Szalai, T.: Geofizikai Közlemények **VIII,** 1960. — 27. Szentes, F.: Földtani Intézet Évkönyve **XLIX,** 741, 1961. — 28. Széky-Fux, V.—Barabás, A.: Földtani Közlöny **LXXXIII,** 217, 1953. — 29. Széky-Fux, V.: Földtani Közlöny **LXXXVII,** 63, 1957. — 30. Szőts, E.: Geologica Hungarica. Series Geologica. **9,** 1956. — 31. Telegdi Roth, K.: Földtani Szemle 1927. — 32. Vadász, E.: Bányászati és Kohászati Lapok **LXVIII,** 1935. — 33. Vadász, E.: Bauxitföldtan. Akad. Kiadó, Budapest, 1951. — 34. Vecsey, Gy.: A bakonyi Ajka—Urkút—Halimba környékének eocén képződményei. Manuscript. Budapest, 1939. — 35. Végh, S.: Földtani Közlöny **XCI,** 273, 1961. — 36. Vitális, I.: Bányászati és Kohászati Lapok **LXV,** Vol. 18—19, 1932. — 37. De Weisse, I. G.: Mem. Soc. Vaud. d. Sci. Nat. 59, **9,** No 1. 1948.

БОКСИТОВОЕ МЕСТОРОЖДЕНИЕ В. С. ХАЛИМБА

М. ЭРДЕЛИ

Р е з ю м е

Это крупнейшее месторождение бокситов страны налегает на верхнетриасовые доломиты и дахштейнские известняки. Породы лежачего бока бокситового месторождения находятся в тектоническом контакте, обусловленном досенонскими тектоническими движениями. После этих движений рассматриваемый район поднялся, был размыт до стадии пенеплена и в карстовых воронках образовавшейся таким образом на поверхности, отложились бокситы. Кровля месторождения представлена верхнемеловой толщей, начинающейся терригенными осадками, постепенно развивающимися из меловых отложений; а затем она продолжается угленосной толщей, которая переходит в морскую толщу осадков. В части месторождения кровля представлена верхним эоценом, а именно там, где меловая кровля была размыта.

На основании результатов и документации 700 колонковых буровых скважин, анализов 3400 проб бокситов и детального изучения керновых проб автор доказывает переотложенность рассматриваемого месторождения. Вряд ли имеются такие скважины, в которых не имелись бы доказательства в пользу переотложения в бокситовых кернах. Это прежде всего бокситовые глыбы, куски, гравии в «основной массе» бокситов, кроме этого, угловатые и окатанные обломки подстилающих месторождение пород, а также масса выветрелых пизолитов, часто в наслоенном состоянии, выветрелые желваки пирита, зерна кварцевых песков, гальки, глинистые глыбы. Наряду с перечисленными образованиями встречаются слоистые-пластинчатые бокситы и глинистые прослои, разделяющие бокситовые тела. Бывает, что участок бокситового тела мощностью всего 30 см подстилается непосредственно углистыми глинами, мощность которых достигает даже 2 метров, в других случаях бокситовое тело разделяется прослоем угленосной глины.

Результаты анализов буровых кернов бокситов показывают, что обнаруживающие следы переотложения бокситы являются совсем слабыми по качеству, причем качество их прихотливо изменяется. Особенно справедливо это для содержания карбоната, ведь наиболее часто встречающимся посторонним элементом рассматриваемого бокситового месторождения является обломочный материал лежачего бока карбонатного литологического состава.

По своему литологическому составу терригенная кровля бокситового месторождения еле разделима от бокситов. Переход является постепенным, разделение кровли от руды является искуственным, основывающимся на химическом анализе материала обоих образований. За боксит принимается порода с кремневым модулем свыше 1. Естественно, что бокситовое тело во многих местах разубоживается нерудним веществом, характерным для вещественного состава кровли, что тоже является результатом процесса переотложения.

Имеются останцы бокситового пласта, залегающего над верхнемеловыми отложениями, а именно на поверхности верхнемеловых гиппуритовых известняков.

Верхнемеловые отложения свидетельствуют об интенсивности имевших место между верхним мелом и нижним эоценом тектонических движений, что сказывается на сильной раздробленности бокситового месторождения и его кровли, так как гиппуритовые известняки более высоких горизонтов меловой кровельной толщи встречаются в виде изолированных «островов», представленных глубоко погрузившимися глыбами.

В бокситовой залежи имеются также доказательства в пользу сильных движений сжатия, о чем свидетельствуют буровые керны.

Наибольшую мощность и наилучшее качество бокситовое месторождение имеет на контакте с породами лежачего бока, где бокситы больше всего раздроблены и наиболее сильно закарстованы. Большая часть месторождения находится под уровнем карстовых вод. Трещиноватые, ноздреватые верхнеэоценовые известняки угрожают опасностью прорыва воды, судя по опыту добычи угля в соседнем районе. По данным буровых скважин, карстовые ходы лежачего бока хорошо закупорены до глубины 15—20 м глиной и бокситом, так что опасные прорывы воды из лежачего бока видимо не произойдут.

A GEOLOGICAL DESCRIPTION OF THE UPPER TRIASSIC AND OF THE COAL BEARING LOWER LIASSIC COMPLEX OF THE MECSEK MOUNTAINS

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Ladinian—Carnian—Norian—Rhaetian—Hettangian—Sinemurian series of the Mecsek Mountains (Fig. 2), mainly the formations underlying the coal complex have been investigated based on the results of recent drilling and mining.

The geological history of the Mecsek mountains and of the areas related to it was compared. It was found that the highest point of the Upper Triassic — Lower Jurassic emergence occurred not in the Rhaetian but in the lowest section of the group of deposits.

The Hettangian and Sinemurian coal complex attaining a thickness of 800 m, with its 14—25 minable coal seams, was laid down in the course of a continuous sedimentation, during the Rhaetian stage.

According to the major structural evaluation of Supplement 1, the major structural characteristics of the Mecsek mountains are determined by monumental-size folded forms and repeatedly rejuvenated tectonic belts.

Problems concerning the Triassic—Jurassic boundary

The Triassic-Jurassic sequence of the area under discussion is of a varied evolution with an intermingling of Middle German and Alpine characteristics. While the Triassic and Jurassic marine formations can generally be well distinguished from each other, faunistically the form province of *Phylloceras* alone crosses the Rhaetian-Liassic boundary, the geological delineation according to rock facies is often impossible. In the homogeneity of the rock facies, the Old Kymmerian orogenic phase had an important role. In the mountain area the transition is epicontinental, or rather continental; that is, a faunistic delimitation encounters difficulties.

The Alpine and the German Triassic distinction used to indicate Triassic marine or epicontinental evolution respectively is hardly applicable in the area. The multicoloured Werfen series with which commences the Lower Triassic of the Mecsek, the Middle Triassic which is "Alpine shell limestone" — according to J. BÖCKH, the Upper Triassic sediments of the "continental" character remind one of the tripartite division of the German Triass. The Cephalopoda fragments of the Middle Triassic, however, show a close affinity to Alpine forms. The sequence regression of the Upper Triassic reminds us of the mingled development of the Western Alps and in some places that of the Tatrides (Fig. 1).

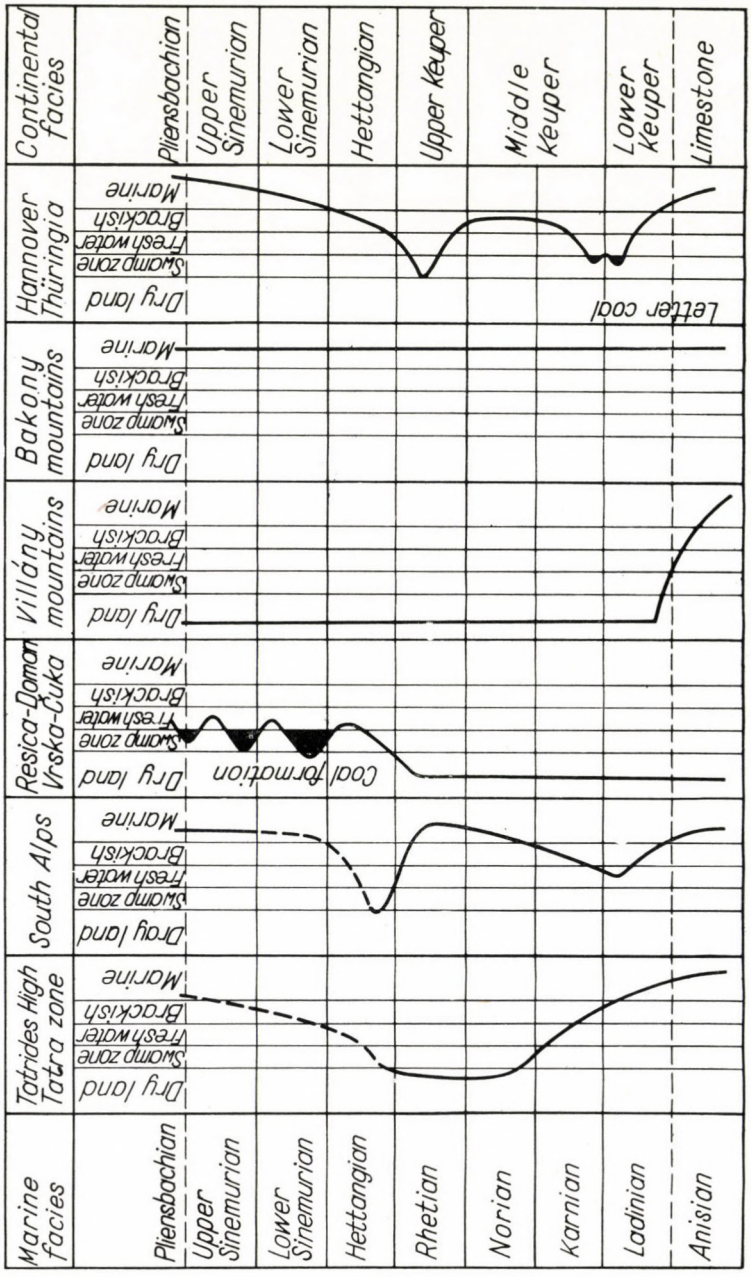

Fig. 1. A few comparative schemes of evolutional history

SLAVIN argues for an independent Rhaetian stage [30]. The "infraliassic" revealing the Swabian facies province, gradually passes into the Jurassic, while the Rhaetic stage of the Alpine Triassic is in close relation with the sediments of the Noric stage. If these facts are compared to those in the present area, it is seen that such a separation is practically impossible. Similarly, if the Ladinian-Rhaetian continuous sedimentation, of irrefutable basin development, be accepted, then the close affinity with Noric and Rhaetic stages characteristic of the Alps, is noticeable; but then the definite gradual transition from Rhaetic to Liassic is no more observable, latter being the characteristic feature of the Keuper series of the German Triassic. The psammitic character of the series as well as the lack of chemogenic material together display kinship with German occurrences.

Mention should be made to a similar special feature regarding the lower and middle continental and near-littoral formations too. In our opinion, explanation for the intermixing can be sought for in the large superficial extension of the older Variscides.

VADÁSZ and SZENTES assume a Paleozoic geoanticline of large extension between the Transdanubian Central Mountains and the South-Baranya island mountains [32, 28]. A region of crystalline slates and granite also must be reckoned in the southern foreground of the Mecsek mountains. The clastic material of the littoral sedimentation was furnished by these very areas, during the period which is a matter of dispute.

A comparison of the relations of geological history is schematically given in Fig. 1. In details, all of them show some similarity, but when the entire series is considered, some difference is more or less always present. The Old Kymmerian regression following the Anisian stage may be taken as a general feature all over the area. In the Hannoverian German formations at a stratigraphical horizon nearly identical with that of the Mecsek, coal is present. In the individual formations, the German "Infraliassic" or the Alpine "Norian-Rhaetian" feature is manifest along the Triassic-Jurassic boundary. Finally it can be established that the Lower Jurassic transgression, with the exception of Villány, is characteristic of all the areas.

Geological development

Marine shallow water Triassic limestones and dolomites cover large parts of the western Mecsek mountains. In the top portions of this succession bituminous limestones, marls and shales are met with which considerably resemble the Wengen formations of the southern Alps. The former series contains intercalations of authogenic breccia which according to VADÁSZ [33] indicates a rapid regression.

The Upper Triassic series shows a similar continuous transition to the bituminous shales of the Ladinian. A relatively rich fauna was found in the transition layers, though not a horizon indicator, nevertheless indicates the

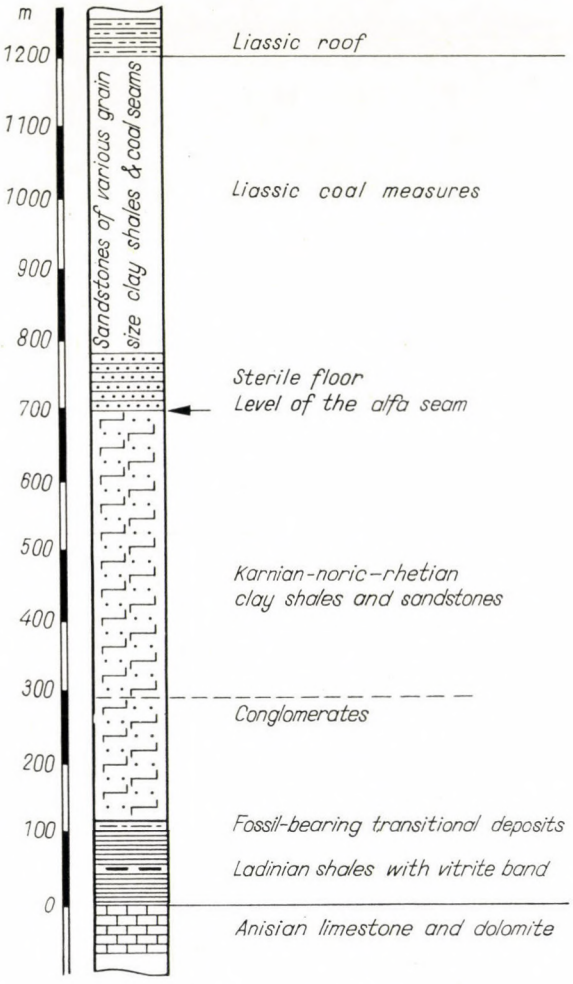

Fig. 2. The stratigraphical column of the Upper Triassic—Lower Jurassic basin development in the Mecsek

Norian stage, by analogy. Its fauna is: *Naticopsis uhligi*, Klipst., *Amauropsis sp.*, *Panopaea sp.* Besides this a large quantity of not determinable shell species was also found. The flora remnants determined *(Equisetites münsteri* Sternb., — *arenaceus* BGT., *Baiera taeniata* Bp., *Schizoneura paradoxa* SCH. et Mo., *Crossotheca sp.*, *Diconitocarpidium sp.*, *Alvies sp.)* are, according to the opinion of some authors, older than the known Rhaetic-Liassic flora of the Mecsek.

Over the characteristically regressional transition series, the sequence called as "Rhaetian sandstone" appears without a stratigraphical gap. Its flora refers, according to STUR's determination, to the Northern Bavarian Rhaetian stage: *Zamites distans*, Presl., — *distans Presl. var. longifolia* Presl., *Palissya bronni*, End., *Thamatopteris brauni* Popp.

The fauna of the series underlying the coal group is poor: *Cardinia hofmanni* Böckh., *Acrodus minimus* Ag., *Estheria hungarica* Vad., *Coelostilina sp.*, *Natica sp.*

Recently, NAGY separated several stratigraphical horizons in the hitherto unspecifiable layer complex according to organic materials collected from bore columns [17]. In his work he succeeded in detecting *Semionotus* and *Estheria facies* characteristic of the German Keuper; further he described — according to his preliminary notice — some *Acteonina (Cylindrobullina) cf. scalaris* and *Pleuromya cf. ambigua* molluscs.

Extremely thick and country's unique clastic series not only resembles the German Triassic but also the southern Carpathians as far as the development is concerned. Its clastic material may be traced from the area in the north of the Mecsek (from the so-called Paleozoic geoanticline) and also to the granite-crystalline slate area between the Mecsek and Villány Mountains. According to the latest discoveries, slightly abraded conglomeratic layers consisting of Middle Triassic dolomitic and limestone material several hundred meters thick were found in boreholes sunk on the mountain margins.

Facies and geochemical investigations made it evident that a very slow regression leads from the underlying formations to the seam group. The highest point of the Upper Triassic — Lower Jurassic emergence occurred not in the Rhaetic, but in the lower section of the seam group [23]. The industrially most important series of the Mecsek, the coal complex deposited in the Hettangian and Sinemurian stages was developed by a continuous sedimentation from the Rhaetic.

The rock types of the coal complex reveal rather a monotonous character resulting from the conditions of formation. It consists mainly of clastic rocks gradually turning into caustobiolites, and chemical sediments, respectively. The series is made up of gritty coarse-grained sandstones, coarse-, medium-, small and fine-grained sandstones, aleurite, powdery slatey mudstone, slatey mudstone, limy slatey mudstone, clay marl, marl, lime-marl, clayey limestone, sideritic slatey mudstone, clay ironstone and their variation, further of coal-bearing slatey mudstone, clayey coal, coal and relatively younger trachydolerite, phonolite and andesite.

In order to illustrate the sediment composition of the subjacent layers and the measures, the relationship of pelite and psammite, and of chemical sediments are shown in Fig. 3. The variation of psammitic sediments reminds one of the mode of evolution (Fig. 4), according to which the mostly detrital

and at the same time "most dry" part of the series is to be sought for between the seams 10 and 17, at Komló. A striking symmetry is shown by the sedimentary series, which indicates that only one lithological cycle of emergence and submergence was operative between the Anisian and Lias series.

During the extended mining of more than one and half century a rich flora and fauna was unearthed. Among the most important flora elements the

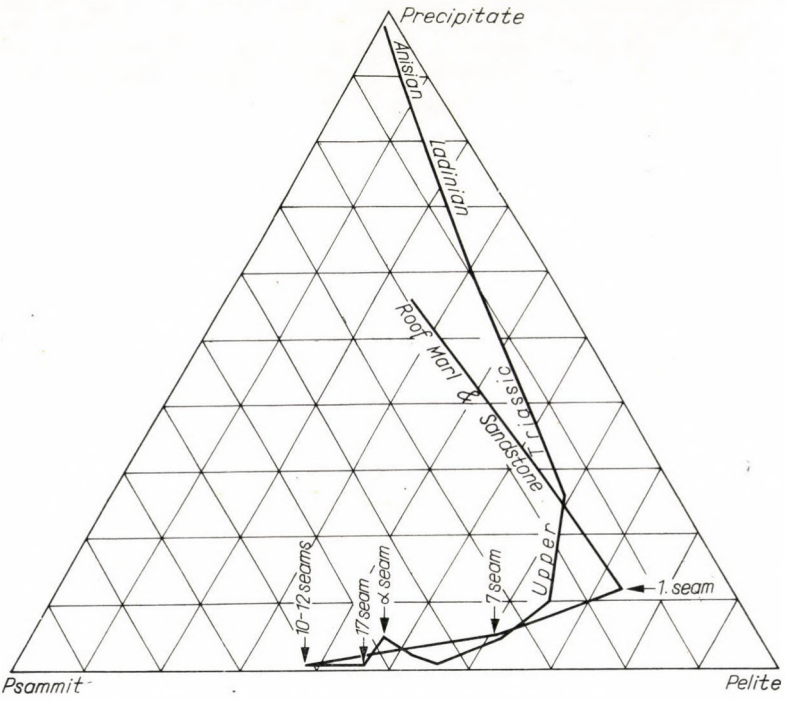

Fig. 3. The approximative sediment composition of the Upper Triassic—Lower Jurassic series of the Mecsek

following deserve a mention: *Equisetites münsteri* Stern., —? *ungeri* Ett., *Todites rosserti* (Presl in Sterb) Kryst., *Phlebopteris brauni* (Goepp) Hirm et Hörh., *Phlebopteris münsteri* (Schenk) Hirm et Hörh., *Clathropteris meniscioides* Brong., *Thaumatopteris münsteri* Göpp., — *münsteri Göpp. var. longissima* Schenk., *Thinnfeldia rhomboidalis* Ett., *Sagenopteris nilssoniana* (Bgt) Ward?, *Taeniopteris tenuinervis* Brauns., — *aff. stenoneura* Schenk., *Nilssonia aciminata* Presl., *Gikgoites marginatus* (Nath.) Florin., *Podozamites lanceolatus* (Lindl. et Hutt.) F. Braun., *Palyssa sphaenolepis* (F. Braun) *Nathorst.* The most frequent members of the flora are the fern-trees and the gingko varieties. According to climatic demands of the members, the climate during the formation of the coal deposits was wet, hot and of a tropical to subtropical nature.

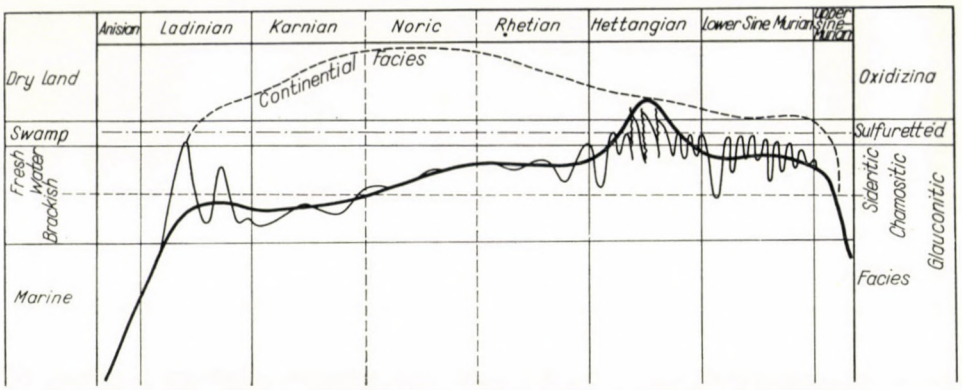

Fig. 4. The scheme of the evolutional history of the Upper Triassic—Lower Jurassic basin development of the Mecsek

Out of the comparatively rich fauna, the following are worth mentioning: *Ostrea irregularis* Münst., *Plicatula crucis* Dum., — *acuta* Vadász, — *(Harpax) striatocostata* Vadász, *Anomya mortiletti* Stopp., *Lima praelonga* Mart., — *(Plagiostoma) exaltata* Terqu., *Gervilleia inflata* Schafh., — *obliqua* Mart., — *conimbrica* J. Böhm., *Perna infraliasica* Qu., — *petersi* Vadász, *Mytilus liasicus* Vadász, *Avicula capellinii* J. Böhm, — *pannonica* Vadász, *Trigonodus cizeri* Vadász, *Cardinia cf. concinna* Sow., — *listeri* Sow., *Isocyprina rotundata* Vadász, *Phacoides problematicus* Terqu., *Trapezium cf. compressa* Terqu., *Astarte cf. chartroni* Cossm., *Cardium (Nemocardium) phillippianum* Dkr., *Pleuromya pannonica* Vadász, *Ceromya infraliasica* Pet., *Neridomus liasicus* Dkr., *Oncochilus climenae* Gemm., — *calypso Gemm. Promathildia turritella* Dkr., *Coelostylina liasina* Terqu., — *nana* Terqu., *Coroniceras bucklandi* Sow., — *rotiformis* Sow., *Arnioceras cf. semicostatus* Y. et B.

During the period of Lower Cretaceous orogeny and the Helvetian transgression, the Mecsek was a dryland. As a consequence, the coal complex was at places more or less entirely abraded. Accordingly the extension of the complex, as seen today, is limited to a considerably smaller area as compared to that of the former basin of sedimentation. As to its extension, it can be divided into two large unites: the comparatively more undisturbed southern part of Pécs—Komló, much more important for mining, and the northern Magyaregregy—Szászvár—Nagymányok—Ófalu range, of extremely complicated structure, dismembered by structural imbrications. The thickness of the complex is 800—900 m around Pécs, 400—450 m at Komló, and in the north it is 150 m on an average on account of absence of layers and also due to roll-outs.

In the Pécs area there are 14—25 coal beds which could be systematically mined; in the Komló basin the minable deposits consist of 17 beds. The beds are numbered from the bedrock towards the cover in the Pécs area whereas it is just the reverse in the Komló area. The thickness of the minable beds, in

the first place that of the main beds, increases gradually towards Komló. In the northern range the development of the deposits is rather capricious. This is expressed in extreme lenticular forms. Consequently the thickness of the deposits varies considerably, proven also by the fact that, unlike the southern basin, here the number of minable beds is only 9 at Szászvár, 1 at Máza and 2 at Nagymányok.

In the coal series beneath the upper paralic and middle limnic section, another slightly paralic series makes its appearance. The seams [16, 17] of the complex are feebly paralic, the main seams [10, 12, 14] are decidedly limnic and the cover seams are again strongly paralic. (The numbering of the seams refer to the Komló basin.) It is in this that we see the difference, too, between the nearby foreign coal areas of similar age [37]. Between Bánát, (Brasov, Vrska Cuka, etc.) and the occurrences of Mecsek mountains (Figs. 1, 4). In Roumanian and Yugoslavian the Upper Triassic transgression is uniform, the formation being definitely of terrestrial (erosional). The series was laid down on the surface as a continuous process, the resulting succession, starting from abrasion conglomerates up to the marine limestones displaying no break in between. The Triassic of the Mecsek is on the other hand marine; regression appears at the end of the Middle Triassic, however the sequence is interrupted only on the margins.

As an effect of the volcanic activity that commenced in the early Cretaceous, or, according to certain authors, already in the Jurassic [1], the trachydolerite lava broke through the coal complex in some places along preformed fractures, mostly, however, along irregular fractures. In the coal and coaly slatey mudstones of weaker resistance intrusions are frequent. In such cases the seam, in a shorter or longer extension along strike and dip, was partly melted or coked by the trachydolerite vein (Fig. 5).

The coal complex cannot be delimited even against the cover. The increase in the subsidence of the sediment reservoir is indicated by the perpetuated formation of clastic rocks and the cessation of coal-formation. The volume of sandstone and quartzite gradually increases. This part of the column is termed jointly as covering sandstone complex. Parallel with the increase of the depth of the sea, the covering sandstone complex is followed at the beginning by clayey marls containing sandstone-layers, succeeded, along with a gradual discontinuance of sand content, by grey, dark grey laminated-schistose clay marls. The covering sandstone and the covering marl complex fills up the entire Sinemurian stage and may be regarded in the Mecsek as the closing member of the Lower Liassic.

In order to promote a practical distinction between the industrially most important formations and the underlying rocks, Supplement 1 is presented. The lithological characteristics described in it are indispensable in practical rock determination.

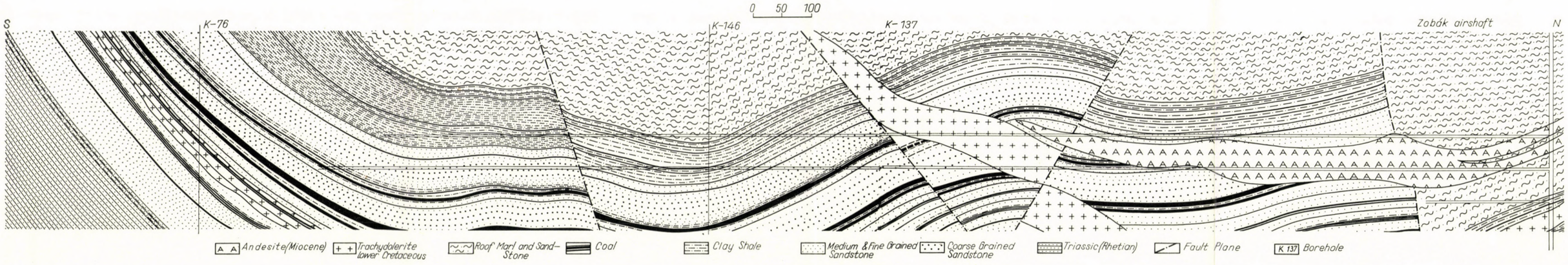

Fig. 5. Geological section across the area of Komló, Zobák-N, Zobák-S and Béta-N. Drawn by G. MAJOR and GY. GAÁL

Structural conditions

Tectonically Mecsek displays folded forms of monumental size. These forms are evident on the contour map indicating the underlayer of the coal complex. One of the main structural elements determining the major structure, namely the central brachyanticline, affects the series under discussion. The northern trough, showing periclinal dips, is built up towards the surface by Jurassic and Cretaceous formations. Palaeogeographical conditions did not play any significant role in the areal location of the coal series. The Triassic-Jurassic formations, essentially horizontal during the Jurassic, but continuously subsiding at the same time, were folded — together with the entire Meso- and Paleozoic complex — assumed the present-day configuration after the emergence and erosion of the folded series.

Major structural fault and fracture units are similarly represented on the contour map. The "Southern zone of disturbance" with a NE-SW trend is

Supplement 1

Comparative characteristics of the non-productive rocks of the Upper Triassic and Lower Jurassic productive complex

Main discriminative characteristics	Upper Triassic underlying rocks	Rocks of the Lower Jurassic productive complex
Schistosity	No schistosity	Schistosity frequent
Stratification	Stratification obvious in thicker beds only	Stratification resulting from rithmicity frequent
Transition Layers	Continuous	Sharp
Cracks	Crack system reminding of drying forms in lack of schistosity	Bound mainly to schistosity and stratification
Maximal grain size	Characteristic limestone and dolomite-breccias and conglomerates	Coarse grained sandstones, occasionally fine-grained quartz conglomerates
Cross-lamination	Occasional uncertain cross-lamination merely in the upper part of the complex	Frequent and obvious between seams 6 and 7
Colour	Sandstones: pale grey, Mudstones: grey, greenish grey, green; frequently varicoloured	Sandstones: grey, dark grey. Slatey mudstones: dark grey, black
Oxidation degree $\frac{2Fe_2O_3}{FeO}$ weight %:	0.07—1000.0	0.0001—7.0
Organic material content	Isolated "shreds" of organic origin in the mudstones	Organic material content uniformly high (10—20%) in the pelites
Rest	Spherolitic siderite globules in the upper part of the complex frequent	Spherolitic siderite globules merely in the underlyer of seam 16

dipping nearly 50° towards NW. On the map, essentially the surface outcrops of this tectonic belt are indicated. Similarly the surface contours were traced in the case of the "Northern Overthrust". The remaining tectonic zones are practically vertical in nature.

The structural elements set forth so far never appear along a well traceable plane. The resultants of the displacement and overthrusts consist of numerous smaller echelon-like faults; therefore it is more appropriate to designate them as tectonic belt or zone. From their manner of development, the age relationships are more or less apparent. Transversal elements trending NE-SW that may be placed at the beginning of the Lower Cretaceous are practically the oldest. The structural belt indicating the tectonic outcrop of the Upper Triassic formations, (on the territory of the western Mecsek) the "Northern Overthrust" at Komló and the "Mája-South limiting fault" seem to be, according to our investigations, identical: consequently they may be regarded as parts of a large tectonical line [24].

Formations younger than Mesozoic do not exist in the "Hosszuhetény fault" zone trending in N—S direction. Therefore whether it is of Meso- or Cainozoic age yet remains unclarified.

Southerly directed overthrusting of Pannonian age is indicated by the existence of the "Northern Overthrust" of E—W direction. As a result, the productive series of the Lower Liassic, originating from the norther foreground, was brought near the surface. In the older tectonic belt of the "Southern belt of disturbance" by dint of rejuvenation, overthrusts of Pannonian age are noticeable.

REFERENCES

1. Balogh, S.: Föld. Közl. **XCIV,** 136—137, 1964. — 2. Bárdossy, Gy.—Mrs. Noske—Fazekas, G.: MÁFI Évi Jelentése az 1961. évről, 41—57, 1964. — 3. Fejér, L.: The geological conditions and expansion possibilities of the coal range between Pécsbánya and Hosszúhetény (in Hungarian). Manuscript, Pécs, 1962. — 4. Fejér, L.: A short geological description of the Coal Mining Trust of Pécs (in Hungarian). Manuscript, Pécs, 1964. — 5. Fejér, L.: Bányászati Lapok **8—9,** 506—521, 1958. — 6. Fejér, L.—Somos, L.: Geological description of the SE-Transdanubian Triassic and of the Lower Liassic productive coal complex (in Hungarian). Paper read at Siklós, 1964. — 7. Góczán, F.: Földt. Int. Évk. **49,** 303—312, 1961. — 8. Horusitzky, F.: Földt. Int. Évk. **49,** 267—278, 1961. — 9. Imreh, L.: Földt. Int. Évk. **45,** 53—67, 1956. — 10. Káli, Z.: Cyclicity of sedimentation on the Lower Liassic coal complex of the Mecsek (in Hungarian). Manuscript, Komló, 1960. — 11. Kopek, G.: MÁFI Évi Jel. 177—192, 1953. — 12. Kovács, L.: Földt. Int. Évk. **42,** 1953. — 13. Kovács, L.: Bányászati Lapok, **4,** 243—249, 1962. — 14. Láda, Á.: Földt. Int. Évk. **49,** 855—860, 1961. — 15. Nagy, E.: Földt. Int. Évk. **49,** 295—302, 1961. — 16. Nagy, E.: Földt. Int. Évi Jel. 1961-ről. 35—38, 1964. — 17. Nagy, E.: The geological description of the Upper Triassic of the Mecsek (in Hungarian), 1964. — 18. Nagy, I. Z.: MÁFI Évk. **XLV,** 105—118, 1956. — 19. Nagy, I. Z.: MÁFI Évk. **XLIX,** 475—521, 1961. — 20. Némedi Varga, Z.: Földt. Közl. **93,** 37—53, 1963. — 21. Némedi Varga, Z.: The geological and structural conditions of the coal area of Hosszúhetény (Doctoral dissertation, in Hungarian), 1963. — 22. Peters, K. F.: Über dem Lias von Fünfkirchen (Sitz. d. k. Ak. d. Wiss. Mat.—Nat. Kl. 46, Wien). — 23. Somos, L.: Földt. Közl. **93,** 24—36, 1963. — 24. Somos, L.: Mining geological relations of the transitional Lower Jurassic layers of the Upper Triassic of the Mecsek (Doctoral dissertation, Komló, 1963). (In Hungarian.) —

25. Szabó, P. Z.: The Investigation of Two Karstic Springs of the Mecsek, with a View to the Water Supply of Pécs (Manuscript, in Hungarian, 1953). — 26. Szádeczky-Kardoss, E.: Geokémia, Akad. Kiadó, Budapest, 1955. — 27. Szádeczky-Kardoss, E.: Földt. Int. Évk. **45,** 315—355, 1956. — 28. Szentes, F.: Földt. Int. Évk. **49,** 741—745, 1961. — 29. Szepesházi, K.: Földt. Közl. **92,** 40—52, 1962. — 30. Szlavin, V. I.: Földt. Int. Évk. **49,** 319—325, 1961. — 31. Vadász, E.: Magyarország földtana (The geology of Hungary; in Hungarian). Akad. Kiadó, Budapest, 1960. — 32. Vadász, E.: Földtörténet és földfejlődés (The history of evolution of the Earth). Akad. Kiadó, Budapest, 1957. — 33. Vadász, E.: Mecsekhegység (Magyar tájak földtani leírása). 1935. — 34. Wein, Gy.: Földt. Közl. **82,** 337—347, 1952. — 35. Wein, Gy.: Földt. Int. Évk. **49,** 759—768, 1961. — 36. Wein, Gy.: Bány. Lapok **10,** 652—655, 1962. — 37. România földtana (The geology of Roumania) Manuscript by the University of Kolozsvár, 1957.

ГЕОЛОГИЧЕСКОЕ ОПИСАНИЕ ВЕРХНЕТРИАСОВОЙ И НИЖНЕЛЕЙАСОВОЙ УГЛЕНОСНОЙ ТОЛЩ В ГОРАХ МЕЧЕК (ЮЖНАЯ ВЕНГРИЯ)

Л. ШОМОШ

Р е з ю м е

Толща ладинского, карнийского, норийского, рэтского, геттанжского и синемюрского ярусов в горах Мечек (рис. 2) — главным образом отложения, подстилающие угленосную толщу — изучалась по данным новейших результатов, полученных по буровым скважинам и в подземных горных выработках.

Была сопоставлена история геологического развития Мечекского района с историей районов, связанных с областью гор Мечек. Максимум верхнетриасового-нижеюрского поднятия наступил не в рэтское время, а в период накопления нижней части угленосной толщи.

Из отложений рэтского яруса беспрерывной седиментацией развилась угленосная толща геттанжского и синемюрского ярусов, мощность которой достигает даже 800 м, с 14—25 промышленными угольными пластами.

Согласно мегатектонической оценке приложения 2, метатектонический характер Мечека определены складчатыми формами монументальных размеров и несколько раз возобновлявшимися тектоническими зонами.

CONTRIBUTIONS TO THE KNOWLEDGE OF THE ORIGIN OF UPPER PANNONIAN QUARTZ SAND IN HUNGARY

By

P. SZATMÁRI

STATE ENTERPRISE FOR ORE AND MINERAL MINING

In the archipelago-type Upper Pannonian sea of Hungary there occurred a rapid detritic sedimentation due to the preceding phases of mountain building. Rapid erosion prevented the direct formation of monomict sands out of polymict rocks. Detritus previously enriched in quartz was represented by the poorly consolidated Miocene deposits overlying the hard Palaeozoic—Mesozoic formations. Accumulation of Miocene detritus was largely the result of the erosion of crystalline masses now covered under the younger deposits of the plains of Hungary. The last and most thorough reworking of the sediment took place in the Upper Pannonian: Miocene sands were eroded off the older formations and deposited along the shores of the islands in the Pannonian sea. The low salinity and high organic content of the waters, particularly close inshore, intensified chemical weathering and tended to keep the variable constituents (Ca, Fe) in solution. The resulting deposits of white quartz or oligomict sands were accompanied inshore frequently by a lagoon-type inner shore zone with clayey deposits in the lagoons shut off the streams and with coarse gravelly-sandy deposits in the lagoons connected with them. Estuary deposits exhibit characteristic diagonal stratification. Further offshore, the zone of white quartz sand grades into one of yellow sand high in iron and lime, whereas in the basin itself aleurite and clay are deposited. On an open shore the inner shore zone was frequently absent, the white sand belt being narrower than 200 metres, whereas in a semi-closed embayment the lagoon sometimes attained substantial width, and the white sand belt could be as wide as 1 kilometre.

Of the quartz sand formations developed around the individual islands of the Upper Pannonian sea, that of the Bakony Mountains is the most significant. Around the Mecsek Mountains the small area of the Miocene deposits, around the Buda and Vértes Mountains the straight open shore inhibited the formation of substantial volumes of quartz sand, whereas in the Mátra and Bükk Mountains erosion of the volcanics together with the Miocene detritic deposits permitted at best development of oligomict sands.

The quartz sand is a transgressive deposit all over the country. Its rate of accumulation was slower than that of the simultaneous sinking of the basin. In the Bakony Mountains, the initial transgression took place in two steps in several places, a fact that may suggest crustal displacement of a small-amplitude between the two steps.

Processes of sedimentation

Tectonically, the quartz sand formation of orogenic regions is a facies of the molasse formation, deposited in dammed-off foredeeps of mountains risen in previous phases of orogeny. The formation of oligomict sand or quartz sand is made possible by intense chemical weathering in humid areas, in a single protracted phase in tectonically undisturbed areas or in several phases of rapid denudation in orogenic ones. In the latter case, however, the denudation of polymict rocks such as granite, quartz porphyry, Permian feldspar-bearing

sandstone can at best lead to the accumulation of mesomict sands. The base material previously enriched in quartz from which the Hungarian Upper Pannonian sands formed was furnished mainly by the clastic sediments of the Miocene. In the gravel material of these latters one encounters besides metamorphic rocks also fairly numerous pebbles of a white granite variety being in the course of kaolinization. The erosion of a similar granite is indicated also by the Palaeogene kaolinitic quartz sands of Sárisáp near Dorog. Neither this kaolinitic granite, eroded in the Miocene, nor the accompanying metamorphic rocks were uncovered at the time of the deposition of the Upper Pannonian sediments. The Hungarian Upper Pannonian quartz sand deposits represent, then, the repeatedly reworked material of metamorphic rocks and a white granite liable to kaolinitic decomposition, in a spell of rapid denudation that did not lend itself for the direct formation of quartz sand out of polymict rocks.

An important property of industrial-grade quartz sand is the absence of variable components (lime and limonite). The absence of lime is a consequence of high concentrations of CO_2 in the waters, the organic material necessary to bring about these high concentrations being furnished by the lignite formation not infrequently connected with the quartz sand. The absence of limonite is the result of a number of interacting factors. Namely, in spite of the fact that the distribution of the absolute quantities of quartz, calcite and limonite in profiles at right angles to the seashore is fairly similar, the abundance of quartz decreases towards the interior of the basin at a much faster rate than those of the variable components. Consequently, the data on relative abundances, the only accessible ones, exhibit an apparent minimum of Fe and Ca in the main zone of deposition in the littoral belt. On the other hand, the low salinity of the Pannonian intramontane sea was insufficient to precipitate the iron discharged into the basin largely in the form of organophilous colloids, particularly in the proximity of inflowing fresh-water streams and of longshore marshes. Towards the interior of the basin the salinity increased somewhat, thus improving the conditions of both colloid and lime precipitation.

Lime- and limonite-free quartz sand is, then, formed along shores characterized by simultaneous lignite formation: the intense chemical weathering resulting in the enrichment of quartz is connected with a hot, humid climate, while the increased organic content of the water in the basin inhibits the precipitation of the Fe and Ca ions and promotes the kaolinitic decomposition of the easily weathered silicates still present in the association (kaolinite — quartz — lignite paragenesis).

All these conditions are optimally satisfied on the shore of the Upper Pannonian intramontane sea: the phase of orogeny at the limit of the Lower and Upper Pannonian substages resulted in a last reworking of the Neogene detritus after which the reworked sands could still deposit on a wave-washed shore of a large body of water. By the beginning of the Lower Pannonian the

salinity of the transgressing sea dropped to a low not attained before, and some embayments became filled with fresh water: the widespread longshore marshes resulted in a low p_H over large areas and in an increased concentration of organic matter.

Quartz sand was of necessity accumulated mainly on the shores of the larger islands, particularly where the shoreline was dissected by halfclosed bays and inlets. The quartz sand formation thus originated comprises a number of well-defined facies. An inner shore zone, an outer shore zone and a sublittoral zone can readily be distinguished.

a) By the *inner shore zone* is meant that part of the littoral zone which is protected from the surf of the open water by sand bars due to longshore currents. In the still water of the inner shore zone large amounts of clayey sediment are deposited. Deposits formed near the mouths of rivers and creeks, rich in coarse detritus, and purely clayey deposits formed farther away from the same, may be distinguished.

The *lagoons adjacent to the rivermouths* catch the whole volume of waste (gravel, sand and clay) carried by the streams. The deposits are mostly banded, finely stratified: it is frequently possible to distinguish the coarser bands of the rainy seasons from the clayey bands of the drier ones. In case the catchment area of the stream covers a largely clayey region, the lagoon receives a vast volume of clay, particularly striking if the clay is of a vivid colour (Permian red aleurolite, Western Mecsek Mountains; reworked bauxite, Fehérvárcsurgó).

In the *lagoons shut off from the rivermouths* the deposits are exclusively clayey. Low salinity and still water result in a scarcity of ferrous precipitations. The redeposited clays found in the lagoon are white, kaolinitic or greyish-blue, kaolinitic-pyritic, the latter being subsequently oxidized to a yellowish-brown colour (Bakony Mountains, Kővágóörs). In the lagoon there may exist some primitive form of plant life resulting in the deposition of black muck, not oxidized even in the course of the epigenetic processes (Mecsek Mountains: Kán, Bakony Mountains: Fehérvárcsurgó).

b) The *outer shore zone* is the littoral zone outside the sand bars or in areas where no sand bars exist, exposed to the surf. Also in this zone deposits formed close to and farther off the mouths of streams can be distinguished.

The *sandy gravel and gravelly sand* deposited *near the mouths of the rivers* is characterized by beds as thick as 0.5 to 1.0, in places even 5.0 metres. The bedding planes are well-defined surfaces of unconformity, frequently with an angular difference of 5 to 10°. The sudden wedging-out of the deposits is due to the fact that the angle of repose of water-saturated shore deposits increases with increasing grain size, while the relief of the sea bottom rapidly changes with the shifting of the point of inflow.

In some cases the fine-grained deposits of the dry seasons, containing little detritus and mostly precipitated out of a colloidal phase, are preserved

along the bedding planes. The colloid precipitated is mostly limonite, substituted in catchment areas covering largely volcanic regions by loose redeposited tuffs (Bükk Mountains: Eger). The thickness of the colloidal beds is 0.1 to 0.2 metres in general, about one sixth of the thickness of the detritic layer. The deposits of the seasons of abundant waste are mostly white, with what little limonite they contain accumulated in the holes of saprophagous organisms.

In the *white sands* deposited *farther off the rivermouths* the gravel content does not exceed 10 per cent, being 1 to 2 per cent on the average. Gravel is mostly concentrated at the bottom of the layers, in which case the bedding plane is a well-defined surface of erosion with current troughs 1 to 5 centimetres wide, 5 to 20 centimetres deep penetrating the underlying bed (Mecsek Mountains: Bükkösd). The lower parts of the individual beds generally exhibit an arcuate cross-stratification. The individual arches, 0.5 to 1.0 metre long, of an amplitude of 0.2 m, convex downward, represent the perpendicular sections of mostly symmetrical troughs parallel with the wave axis, having mutually eroded each other. The upper parts of the beds exhibit traces of flow ("convolute bedding") and gentle ripple marks of a few centimetres amplitude.

The white sands are excellently sorted with a characteristic single-peak grain size distribution curve. 80 to 90 per cent of the deposit (including also the clayey fraction) consists of quartz. The distribution of heavy minerals conforms to the well-known rule that finer-grained deposits are bound to contain larger amounts of higher-density heavy minerals. In the coarser parts of the sands the heavy aluminum silicates prevail (garnet, sillimanite, disthene), whereas the finer-grained parts mostly contain oxide ores (magnetite, ilmenite, zircon, rutile).

The breadth of the white sand belt is considerably influenced by the trace of the shoreline. In a more or less shut-off embayment (Western Mecsek Mountains; Bakony Mountains: Tapolca Basin, Fehérvárcsurgó Basin) it may attain one kilometre, whereas on an open shore (Buda Mountains, southern margin of the Bükk Mountains) it seldom exceeds 200 metres.

The irregularly distributed insignificant lime content of the white sands is generally concentrated along the inshore and offshore margin of the sand zone, that is, along the line of contact of the white sand with the sandy clay of the lagoon on the one hand and with the yellow sand and the sublittoral clayey sand on the other. In these belts first spherical or stalactite-like vertical lime concretions 0.5 to 2 centimetres in diameter appear, coalescing later on into banks of lime of a few dozen centimetres thickness mostly occurring at the bottom of the layers (Mecsek Mountains: Cserdi, Bükkösd). As stated above, the main reason for this distribution of the lime is the fact that whereas the absolute (annual) maximum of the accumulation of lime coincides with that of the sand, the relative abundance of lime as against that of the sand increases

in the direction of the sedimentary basin and sometimes also in the opposite direction. Further factors influencing the distribution of lime are the nature of the inner shore zone and the shape of the shoreline. In areas where the inner shore zone abounds in lagoons suited to the formation of coaly substances and where the sand is deposited in a more or less isolated embayment, the relatively high abundance of organic matter (CO_2) in the water inhibited the precipitation of any significant amount of lime (Mecsek Mountains: Bükkösd, Bakony Mountains: Kisörs, Fehérvárcsurgó). On the other hand, in areas where the trace of the shoreline is smoother and lagoons suited to the formation of peaty clay deposits are less likely to develop, the limy concretions and limestone banks penetrate also into the white sand belt (Mecsek Mountains: Cserdi, Boda, Buda Mountains: Diósd, Sóskút).

In the interior of the basin (sublittoral zone) where the lime content of the sand is even higher, no lime concretions develop; lime remains in a dispersed state.

The *belt of yellow sands* differs from the white belt in its constitution as well as in its stratification. Its most significant feature is the abundance of dispersed limonite, but to interpret this we have to study first the nature of the stratification.

The thickness of the individual layers varies from 1 to 5 metres. The bedding planes still exhibit gentle unconformities indicating the removal of some sediment. Gravel is however subordinate in the deposit, being generally subsituted by a limonitic crust of a few millimetres thickness. In the sediment limonite is either dispersed or concentrated in bands a few tenths of a millimetre thick. The bands are separated by stripes of white sand 1 to 2 (exceptionally up to 20) centimetres thick containing little or no limonite. The limonitic bands generally form wavelets 5 to 10 centimetres long, and of 1 to 3 centimetres amplitude. Arched cross stratification is nowhere visible. Limonite locally forms concretions a metre across and 1 to 2 decimetres thick, often arranged in strings of quite considerable extent. "Pebbles" consisting of white sand in a coating of limonite of varied thickness and casts of fossils consisting of a limonitic sandstone are also fairly frequent. BARTHA described one instance of the cast still carrying the mother-of-pearl layer of the original mollusc shell. Elsewhere (Bükkösd) one encounters a string of limonitic spherules a few millimetres across in the yellow sand a couple of millimetres above the surface delimiting the white sand against the yellow sand.

Summing up, limonite usually follows the original bedding of the deposits, being frequently linked with surfaces of interlayer erosion. It mostly occurs in sands not very thoroughly agitated by surf (as indicated by the fact that arcuate cross bedding, that is, the truncation of the upper half of the wave is nowhere observed) attaining its highest abundance in the molluscan shell casts.

Among the above features it is particularly the shell fillings that suggest at least part of the limonite having originally been precipitated as iron sulfides, for in the presence of decomposing organic matter no limonite could possibly have formed. This idea is further confirmed by the occurrence of limonite in less thoroughly agitated water. According to J. R. BRUCE one finds at a depth of 5 to 75 centimetres below the surface of Recent littoral deposits a layer of black sand containing a rich bacterial flora. These bacteria are scavengers feeding on the organic matter filtered by the sand out of the continually moving sea water. The p_H of the water in this layer is above 8. In it, iron is precipitated in a sulfidic bond. If the black sand is uncovered, its iron sulfide content oxidizes to a brownish yellow colour.

On the basis of the above-said it is probable that also the yellow sand of the Upper Pannonian sea became limonitized owing to the epigenetic oxidation of its iron sulfide content. Every episode of reworking and redeposition by the waves or by currents obviously resulted in a spell of oxidation and of migration of solutions on the surface of the deposit. It is just as obvious that in the part of the deposit undisturbed by wave action pyrite remained in a randomly dispersed distribution, being uniformly oxidized subsequently to the emersion of the deposit. The limonitic hole fillings observed in the white bands between the limonitic bands are presumably due to the oxidation of the iron sulfides contained in the excrements of the saprophagous animals hidden in the sand.

The grain size distribution and composition of the yellow sand facies more or less coincides with that of the white sand, with the already mentioned exception that the decrease in grain size entails the enrichment of higher-density heavy minerals. Simultaneously also an opposite tendency prevails the increase of the clay and mica content in the sand, induced by the decreasing intensity of agitation by wave action.

c) *The sublittoral zone.* In the intramontane Pannonian sea, tides were absent. Consequently, the limits of the littoral zone have been established on the basis of surf intensity alone. Accordingly, that zone is termed as sublittoral in which the waves only ripple the surface of the sediment, being too weak to whip up whole sand waves and to remove the detritus thus reworked. As a consequence, the clay and aleurite content of the sublittoral deposits frequently surpasses 50 per cent. These deposits generally exhibit a gradual transition towards the yellow sand of the outer shore zone and their inshore side frequently contains interfingerings of micaceous-clayey yellow sand. On the offshore side a fine stratification is characteristic, with the annual alteration of yellowish brown sandy and greenish grey aleuritic bands of 0.1 to 1.0 mm thickness. The sediment is generally limy, its lime content is randomly dispersed. The stratification of the aleurite and clay layers is horizontal, ripple marks of a few centimetres length being restricted to the zone of alterna-

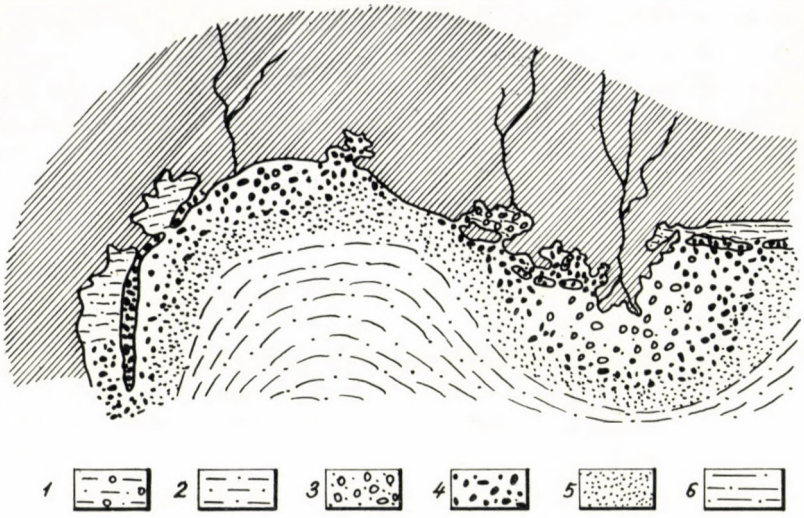

Fig. 1. Diagrammatic representation of the principles of littoral quartz sand formation
Scale cca 1:50 000

1. Inner shore zone, rivermouth lagoons. — 2. Inner shore zone, lagoons shot off from the rivermouths. — 3. Outer shore zone, rivermouth section. — 4. Outer shore zone, white sand belt. — 5. Outer shore zone, yellow sand belt. — 6. Sublittoral zone

tion of sand and clay deposits. The truncated sand waves of the white sand and the undisturbed ones of the yellow sand are absent from this zone.

The settling rates of aleurite, finely dispersed calcite and coagulated clay particles coincide. As a result, the deposition of these in the same environment is a common occurrence. The fine stratification is presumably a consequence of the seasonal changes in the volume of detritus and organic material carried in from the land. Limonite is bound in the first place to the sandy

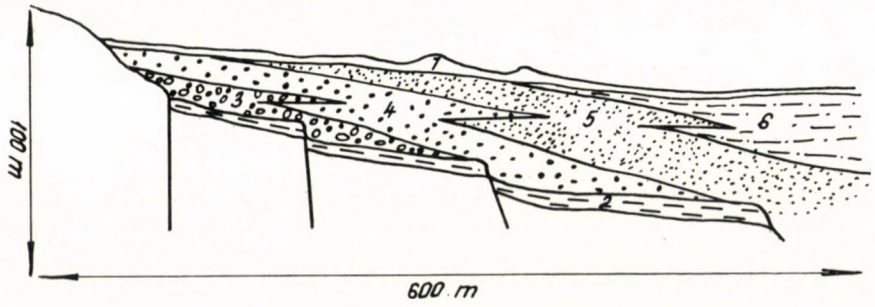

Fig. 2. Sketch profile of the deposits of the outer shore zone

1. Hard shore-forming rock. — 2. Deposits of an ingressional lagoon. — 3. Deposits of the rivermouth section. — 4. White sand. — 5. Yellow sand. — 6. Sublittoral sandy clay. — 7. Quaternary formations

bands, being presumably formed also in this case by the secondary oxidation of sulfidic compounds.

Summing up it may be stated that the outer shore zone wedges out landwards among lagoon deposits, among rivermouth formations or on the basement, and basinwards between the clayey-aleurolitic deposits of the sublittoral zone. Its white sand zone occupies a broad band in half-closed embayments and a narrow one on more open shores (Figs. 1—3).

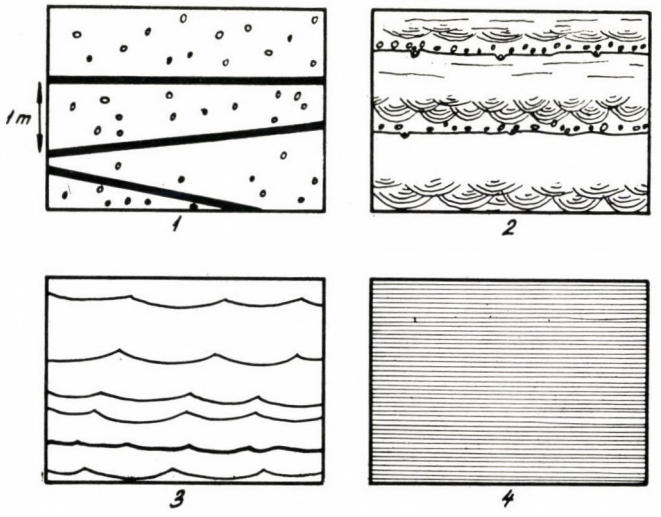

Fig. 3. Main types of stratification of the outer shore zone deposits
1. Rivermouth-type sandy gravels. The strata are outlined by limonitized interfaces. — 2. Stratification of white sand delineated by graded bedding planes. — 3. Stratification of yellow sand delineated by limonite bands. — 4. Stratification of sublittoral sandy clay delineated by limonite bands

In the following we shall briefly review the principal quartz sand formations of the Hungarian Upper Pannonian intramontane sea with special emphasis on the white sand belt (Fig. 4).

Palaeogeographic conditions

Western Mecsek Mountains. From the point of view of quartz sand formation only the western part of the Mecsek Mountains merits attention, because in the east (Boda—Pécs—Pécsvárad) the denudation of the polymict rocks of that area (Permian sandstone, granite) resulted at best in the forma-

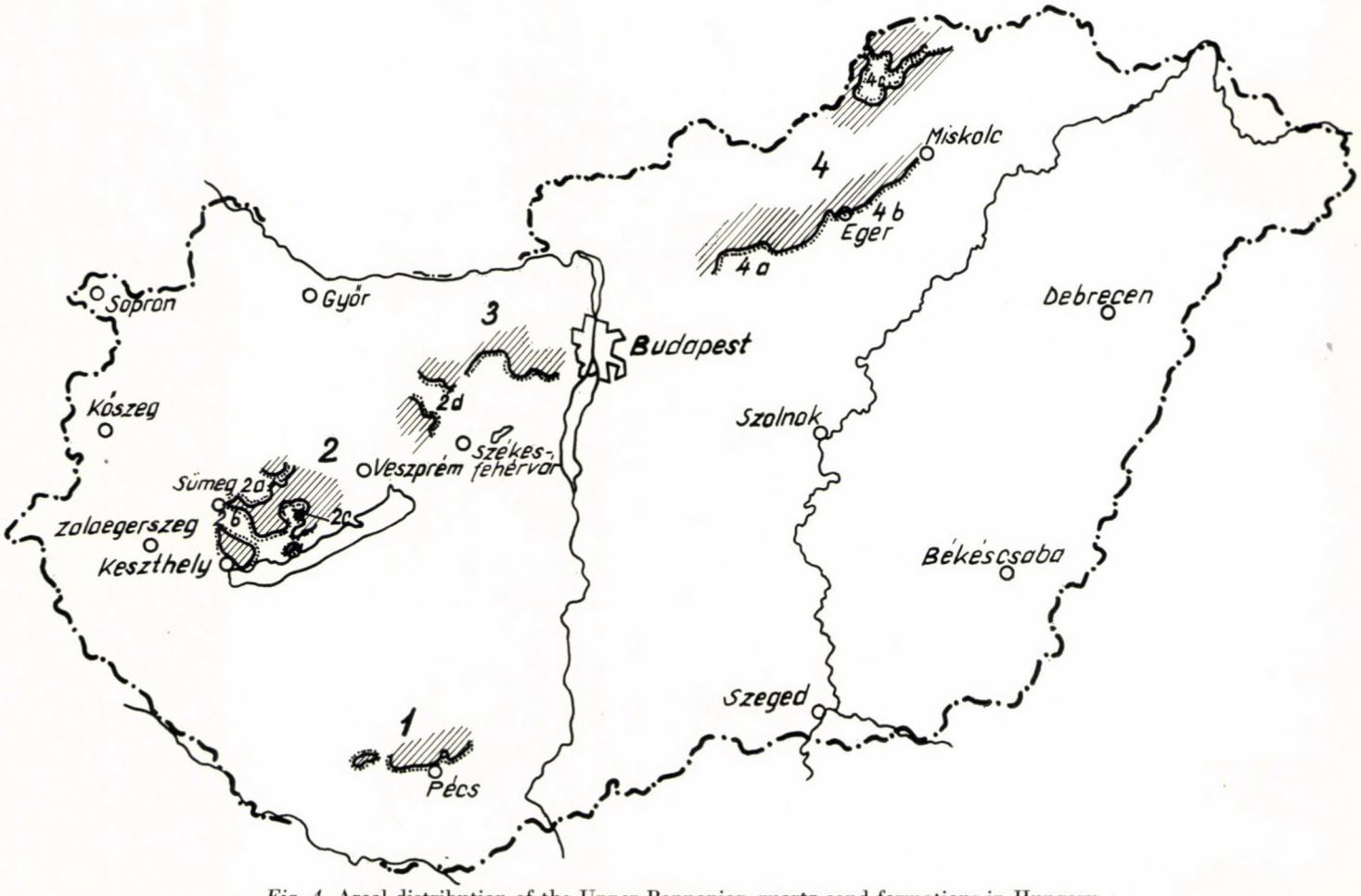

Fig. 4. Areal distribution of the Upper Pannonian quartz sand formations in Hungary

1. Western Mecsek Mountains. — 2. Bakony Mountains. — 2a Nyirád Bay. — 2b. Sümeg Bay. — 2c. Tapolca Basin. — 2d. Fehérvárcsurgó Bay. — 3. Buda and Vértes Mountains. — 4. Mátra and Bükk Mountains. — 4a. Petőfibánya Bay. — 4b. Eger Bay. — 4c. Rudabánya Basin

tion of a mesomict sand. In the Western Mecsek Mountains a half-open bay suited to the accumulation of quartz sand developed in the Cserdi—Kán—Bükkösd region, bordered in the east and north by the Permian sandstone and Triassic limestone mass of the Mecsek Mountains and its thick Helvetian cover, in the west by an island consisting of granite, quartz porphyry and Permian aleurolite. Connected by a channel about 3 kilometres wide with the open sea in the northwest, the basin was fully open in the south.

The rivermouth facies of the outer shore zone around Cserdi is situated on open-shore stretch. The layers 3 to 5 metres thick, wedging out at a dip of a few degrees, are characterized by "convolute bedding", less frequently by a plane-surface cross stratification indicative of a river current, coming from the northwest and the northeast. These directions of transport are confirmed also by the sand and gravel material: from the northeast there arrived mainly the detritus of the red Permian sandstone, from the northwest the reworked material of the Helvetian clastic deposits. The sands are locally interrupted by inner-shore type deposits, constituted in the low-waste seasons by red clayey sands washed out of the Permian rocks and in the high-waste rainy seasons by white sands. Quaternary erosion by the Bükkösd Creek resulted in the removal of the rivermouth deposits from the vicinity of the ancient shoreline. Farther off, however, the basal conglomerate, 1 to 3 metres thick, of the upper Pannonian series exhibits characteristic rivermouth features: the layers, 0.5 to 1 metre thick, are striated by limonitic bands 0.1 to 0.2 metre thick. The gravel is dominated here by the reworked materials of the Miocene deposits (quartzite, white kaolinitized granite, gneiss, upper Carboniferous sandstone). On the shores of the western island, consisting of red granite, quartz porphyry, upper Permian aleurolite, the rivermouth sands are largely composed of the rocks outcropping along the shoreline. Also in this latter case the layers of gravelly sand, 0.1 to 1 metre thick, are separated by striae of limonite about 0.1 metre thick.

The white sand body is thickest inside the bay (25 metres at Bükkösd), thinning out gradually towards the open-shore areas (Cserdi, 5 metres). The gravel derived from the area of denudation is restricted here to the base of the layers of 1 to 5 metres thickness. Current troughs and truncated arcuate half waves are fairly frequent. In the places where it is thickest the white sand complex is clearly subdivided into two members, separated at Bükkösd by a fine-grained sand layer 5 to 10 metres thick, at Kán by a few dozen centimetres of peaty clay. Both indicate the temporary slackening of waste transport, connected at Kán with the temporary cutting-off of part of the basin.

At the limit of the white sand deposit against the yellow sands one observes a development of lime concretions rather subordinate in the bay but intense on the open-shore stretches. The size of the concretions varies from spheres of a few millimetres across to lenticles of several metres diameter and

some dozen centimetres thickness, in dependence on the lime content syngenetically precipitated and diagenetically concentrated. The concretions occur mostly in connection with the finer-grained deposits and with the bedding planes.

The yellow sand belt is characterized by layers 1 to 5 metres thick, containing no gravel, and by limonite concretions and crusts indicating the interfaces of the untruncated sand waves. The strike of the ripples is north-south in the area between the western island and the Mecsek Mountains, bending to fit the shorelines in the near-shore zones.

The sandy clay and aleurite deposits of the sublittoral zone overlie both the white and the yellow sand deposits, with intercalated sandy lenticles in the bottom part of the sequence, indicating the extension of the transgression and the slackening of waste transport. Around Kán the aleurite considerably overreaches the white sands deposited in Miocene depressions and overlies directly the Miocene deposits.

Bakony Mountains. In the Upper Pannonian the Bakony Mountains constituted an island covered with clastic Miocene deposits underlain in the southernmost zone by clastic Permian, almost everywhere else by carbonatic Triassic rocks. The shoreline of the island was dissected by several bays the largest of which are the Nyirád and Sümeg bays, the Tapolca basin, and the baylike depression of the Mór graben separating the Bakony Mountains from the Vértes Mountains. It was in these same bays that quartz sand deposits of some importance came to exist. The Nyirád bay was protected by an island chain of Mesozoic and Miocene rocks, the Sümeg bay by the Triassic mass of the Keszthely Mountains. The Tapolca (Kál) basin penetrated in several inlets deep into the mass of the Bakony Mountains. The Fehérvárcsurgó bay of the Mór graben was limited on the one side by a bend, several kilometres long, of the dolomite shoreline of the Bakony Mountains and, on the other, by a chain of isles of a general NNE—SSW direction between the Bakony and the Vértes. These bays promoted the development of an inner shore zone: in the course of the ingressional rise of the ground water table preceding the Pannonian transgression littoral lakes protected from the inflow of coarse waste and depositing kaolinitic clay, either with or without pyrite came to exist in the Tapolca Basin (Kővágóörs, Kékkút). The pyrite was subsequently limonitized. On the shores characterized by more intense waste transport (Sümeg Bay, Fehérvárcsurgó) these shore lagoons mostly occurred in the vicinity of the creek mouths, and were filled with gravelly-sandy deposits, or, in the case of Fehérvárcsurgó, with bauxitic clay. A lagoon suited to the accumulation of peaty substances developed at Fehérvárcsurgó in a spell of interrupted waste transport: the peaty clay passes gradually into the basin deposits, the transition being indicated by the appearance of lime nodules and the absence of organic matter.

In the rivermouth sections of the outer shore zone sandy gravel deposits came into existence. Its beds, a few metres thick but locally as thin as 0.5 metre, frequently wedge out within a couple of dozen metres. The bedding planes may be marked by strong limonitic bands (Tapolca Basin: Szentbékálla); elsewhere limonite may be scarce (Nyirád Bay: Pusztamiske) or absent (Sümeg Bay: Lesencetomaj). Cross-stratified series characterized by fluvial-type plane bedding surfaces locally occur within the outer-shore deposits: the directions of transport indicated by the slope of the lamination invariably points radially outward from the Bakony Mountains. The gravel is dominated besides quartzite by the kaolinized white granite redeposited from the Miocene. There occur also a few pebbles of fine-grained Permian sandstone.

The width of the white sand belt depends on the trace of the shoreline: at Fehérvárcsurgó it exceeds one kilometre whereas in the open-shore sections of the Tapolca Basin (Kékkút) it is quite insignificant. With increasing distance offshore the sand becomes finer-grained, with an increasing abundance of higher-density heavy minerals. Mineralogically the sand is very pure: its feldspar content is 3 to 5, its heavy mineral content 0.07 to 0.25 per cent. At Fehérvárcsurgó the series is seen to split into two members. The lower member (5 to 30 metres thick) is separated from the upper one (5 to 10 metres thick) by an intercalated layer of peaty clay, 1 to 8 metres thick, thickening towards the interior of the basin.

It is exclusively in the quartz sand formation surrounding the Bakony Mountains that the local silicification of the upper level of the white sand deposit can be observed (Tapolca Basin: Kisörs, Fehérvárcsurgó Bay: Tatár Hill). Silicification is presumably due to the incipient basalt volcanism. The sand was presumably cemented by silica-rich solutions flowing into the water of the sedimentary basin. The cementation resulted in the formation of silicified sandstone lenses one to two metres thick, to be traced in a length of a couple of dozen metres. The springs charged with carbon dioxide still surging in both areas (Tapolca basin: Kékkút, Fehérvárcsurgó Bay: Moha) are probably the late remains of this post-volcanic activity.

The yellow sand zone presents also here diverse forms of occurrence of limonite, and the increased density of the heavy minerals is accompanied also here by an increased abundance of mica and clay minerals. Owing to the abundant waste discharge of the Bakony Mountains catchment areas, basal gravels at the bottom of the sand beds are fairly frequent even in this zone.

The aleuritic-clayey deposits of the sublittoral zone overreach both the yellow and the white sands, indicating a general subsidence of the area of denudation.

Buda and Vértes Mountains. Along the southern shore of this contiguous block of mountains the littoral quartz sand formation can be traced in a length of some 60 kilometres. The area of denudation was covered by Miocene clastic

deposits and limestone, underlain by Triassic dolomite. The shore was mostly open, even gentle bends in the shoreline being rather scarce. Accordingly, the formations of the inner shore zone are absent from this region.

The rivermouth section of the outer shore zone (Sóskut) consists of the alternation of gravelly sand and sandy gravel layers 1 to 5 metres thick. Owing to the above-discussed causes the layers wedge out within short distances. The bedding planes do not carry any limonite. The gravel material of the series mostly comes from the reworking of Miocene clastics, the basement being represented besides quartzite by gneiss and epimetamorphic quartz sandstone and chert derived from Mesozoic rocks.

The layers, 1 to 5 metres thick, of the white sand belt are characterized by an almost parallel stratification and by the high concentration of lime along the bedding planes. Gravel is practically absent. The sand is not as pure as on the shores of the Bakony Mountains: it contains as much as 3 to 7 per cent of feldspar, 1.0 to 1.5 per cent of heavy minerals. Of the heavy minerals, garnet is the most abundant (50 per cent), but its concentration decreases towards the interior of the basin. The lime content of the sand is considerable: lenticles of limy sand 40 to 70 metres across are fairly ubiquitous, except in the central band of the white sand zone. The abundance of lime resulting from the open-shore position entails the presence of undissolved fossil shells.

Data on the yellow sand and sublittoral belt are unsufficient as yet.

Mátra and Bükk Mountains. Along the southern margin of these two mountain ranges that behaved as a single contiguous mass in the Upper Pannonian as well as around the mountains adjacent in the north (Szendrő, Rudabánya Mountains and the Aggtelek Karst) there is an uninterrupted zone of sand. The detritus constituting the sands was derived from the Miocene clastics and volcanics (rhyolite, andesite and their tuffs) covering the largely carbonate basement. Considering that, as mentioned above, no quartz sand is formed directly out of polymict rocks in the course of the relatively rapid denudation of orogenic areas, the considerable contribution of the volcanics to the sands permitted at best the development of oligomict sands. These latter carry much more feldspar (and consequently Al and alkalis) and locally also more heavy minerals (and consequently also iron) than the Transdanubian quartz sands. The Rudabánya basin between the Rudabánya Mountains, the Gömör County Karst and the Bükk Mountains is a large, almost completely isolated bay; elsewhere the shoreline of the Mátra and Bükk Mountains is open almost in its whole length, with subordinate embayments near Eger and Egerszalók on the one hand and at Petőfibánya on the other. The deposits of the inner shore zone have not yet been studied.

The rivermouth section of the outer shore zone, narrow near Eger, is several kilometres wide in the Rudabánya Basin and along the contiguous stretches of open shore. This fact suggests that most of the detritus carried off

the Bükk Mountains was spread in a northerly direction. Sandy gravel and gravelly sand beds, 1 to 5 metres thick, of diagonal cross stratification or almost parallel stratification, are separated by limonitic bands 0.1 to 0.3 metre thick. At Eger-Cigléd these limonitic bands are partly substituted by white clayey-siliceous ones, presumably as a result of the redeposition of the Miocene rhyolite tuff. The beds lined by the limonitic bands are white to light yellow, with a considerable number of limonitized traces of burrowing organisms, 10 to 40 millimetres thick. The gravel found in the beds is indicative of a catchment area covering Miocene clastics and volcanics: besides predominant quartzite pebbles of rhyolite tuff, limnoquartzite and andesite are encountered.

The white sand zone is disclosed along the southern margin of the Mátra and Bükk Mountains as well as in the northern part of the Rudabánya Basin. The beds of the sand, 1 to 15 metres thick, are parallel with lenticular intercalations of sandy gravel and green clay, 1 to 10 metres in diameter and 0.1 to 0.2 metre thick. Within the individual layers, convolute bedding, wave ripples and cross-stratified packs of 0.2 metres height due to cross-bedding in a current can be observed. In the open-shore sections cylindrical lime concretions 2 to 5 mm in diameter, 20 to 100 centimetres tall, are fairly frequent. The heavy mineral content of the sand is 0.3 to 0.03 per cent.

The yellow sand zone near Eger is represented by sediments of high mica content. Intercalations of clayey strata 0,1 to 0,3 m thick are abundant in the upper part of the section. The sublittorral zone has not been studied here.

Conclusively the same general pattern of near-shore sedimentation is traceable all over the country. Local modificiations are due to minor differences in the catchment areas and shoreline configurations. Large catchment areas covered by poorly consolidated detrital sediments seem to have served as main sources of the quartz sands, whereas the chemical composition of the waters in half-enclosed bays with fresh-water inflow inhibited chemogenetic sedimentation.

REFERENCES

1. Bartha, F.: MÁFI Évi Jel. 1961-ről, 175—183, 1965. — 2. Bartha, F.: Földt. Int. Évk. **48,** 1—191, 1959. — 3. Sz. Hajós, M.: Összefoglaló földtani jelentés és készletszámítás a Kővágóőrs—Kisőrspuszta-i homok- és kvarchomokkő-kutatásról (Report on the geology and mineral reserves of the Kővágóőrs—Kisőrspuszta sand and siliceous sandstone area). (Manuscript) 1956. — 4. Inman, D. L.: Shore Processes. In Mc Gray-Hill Encycl. of Sci. and Techn. New York. 1960. — 5. Jámbor, Á.—Szabó, J.: Föld. Közl. **91,** 316—324, 1961. — 6. Krizsán, P.: Összefoglaló földtani jelentés és készletszámítás a Kisőrspuszta-Salföld-i homokelőfordulásról. (Report on the geology and mineral reserves of the Kisőrspuszta-Salföld sand area.) (Manuscript) 1964. — 7. Moldvay, L.: Összefoglaló földtani jelentés és készletszámítás a mecseki öntödei homokelőfordulásról. (Report on the geology and mineral reserves of the Mecsek area foundry sand occurence.) (Manuscript.) 1955. — 8. Moldvay, L.: Összefoglaló földtani jelentés és készletszámítás a sóskúti öntödei homokelőfordulásról. (Report on the geology and mineral reserves of the foundry sand occurence at Sóskút.)

(Manuscript.) 1956. — 9. PANTÓ GY.: Összefoglaló földtani zárójelentés és készletszámítás a diósdi öntödei homokelőfordulásról. (Report on the geology and mineral reserves of the foundry sand occurrence at Diósd.) (Manuscript.) 1961, — 10. RUCHIN, L. B.: Grundzüge der Lithologie. (Principles of lithology.) Akademie-Vlg. Berlin, 1958. — 11. SÜMEGHY, J.: Földt. Int. Évk. **32,** 67—157, 1939. — 12. SZÁDECZKY-KARDOSS, E.: Mat. Term. Tud. Ért. **57,** 1938. — 13. SZATMÁRI, P.: A kvarchomokkutatás távlati terve (Prospecting for quartz sand. A 20-year plan). (Manuscript.) 1964. — 14. STRAKHOV, N. M.: Osnovy teorii litogenesa. (Principles of the theory of lithogenesis.) Izdatelstvo, AN. SSSR. Moszkva. 1962.—15. VADÁSZ, E.: Elemző földtan. (Principles of geology.) Akadémiai-Kiadó, Budapest, 1955. — 16. VARJU, GY.: Magyarország nem érces ásványi nyersanyagai. (Non-metallic mineral resources of Hungary.) In: JANTSKY, B. et al.: Magyarország ásványi nyersanyagai. (Manuscript.) 1964. — 17. VECSERNYÉS, GY.: Összefoglaló földtani jelentés és készletszámítás a fehérvárcsurgói üveghomokkutatásról. (Report on the geology and mineral reserves of the Fehérvárcsurgó glass sand area.) (Manuscript.) 1964.

К ВОПРОСУ ОБРАЗОВАНИЯ ВЕРХНЕПАННОНСКИХ КВАРЦЕВЫХ ПЕСКОВ В ВЕНГРИИ

П. САТМАРИ

Р е з ю м е

В верхнепаннонском внутреннем море Венгрии, имевшем характер архипелага, произошла весьма быстрое осадконакопление обломочного материала благодаря предшествовавшим этому процессу горообразовательным движениям. Вследствие быстрого размыва непосредственного образования мономиктовых песков из полимиктовых не имело место. Уже первоначально обогащенный кварцем осадочный материал был предоставлен рыслыми миоценовыми отложениями, перекрывавшими уплотненные, более древние (палеозойские-мезозойские) породы. Эти осадки накоплялись в процессе размыва когда-то приподнятого кристаллического массива существовавшего на месте наших низменностей. Последнее, наиболее интенсивное переотложение осадочного материала имело место в верхнепаннонское время: песчаный материал размытых и снесенных с выходов фундамента миоценовых обломков накопился вдоль берегов островов. Небольшое — в особенности вдоль берегов — содержание солей и весьма большое содержание органических веществ в воде бассейна ускорили процесс химического выветривания и сохранили изменчивые компоненты (Fe, Ca) в растворе. Образовавшуюся таким образом зону белых кварцевых или олигомиктовых песков соответственно, часто сопровождала лагунная внутренняя зона берега, причем изолированные от притоков воды лагуны стали местом накопления глин, а в лагунах около устьев рек накоплялись гравелисто-песчанистые глины. Поскольку поступавшие с суши воды приливались в море на открытом берегу, то около устья реки отложились гравелистые пески с характерной диагональной косой слоистостью. Со стороны бассейна зону белых кварцевых песков окаймляла зона желтых песков с содержанием железа и извести, в то время как в бассейне самом отложились алевролиты и глины. В условиях наличия открытой береговой линии внутренняя береговая полоса часто отсутствовала и даже зона белых кварцевых песков была уже 200 м, в то время как в бухте или заливе лагунная зона часто бывала значительной и ширина зоны белых кварцевых песков достигала даже 1 км.

Из береговых кварцевых песков отдельных островов наиболее значительны пески около гор Баконь: вдоль гор Мечек накоплению кварцевых песков помешало ограниченное распространение области сноса миоценовых отложений, вдоль гор Вертеш и Буда ему помешало наличие нерасчлененного, открытого берега, в то время как вдоль гор Матра и Бюкк денудировавшиеся вместе с обломочным материалом вулканиты позволили по крайней мере образование олигомиктовых песков.

Кварцевые пески представляют собой во всех районах трансгрессивное образование, формировавшееся в процессе накопления обломочного материала, не сумевшего пойти в ногу с опусканием осадконакопительного бассейна. Начало трансгрессии на Задунайском крае было в ряде мест двухфазовым, что возможно и указывает на наличие небольших движений между обеими фазами трансгрессии.

SITUATION PALÉOGÉOGRAPHIQUE DE LA FAUNE DE MOLLUSQUES DU SÉNONIEN DE LA HONGRIE

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L'auteur donne une conclusion des résultats des analyses malacologiques du Sénonien de la Hongrie, tout en esquissant les rapports fauniques et la situation paléogéographique de faune. Les résultats se fondent sur des recherches malacologiques faites dans la région Sud des Monts de Bakony, toutefois on a également pris en considération les faunes des autres formations sénoniennes de la Hongrie (Bakony Septentrional, Monts de Bükk, Bassin de Zala), pour ce qui concerne le dépouillement faunistique, stratigraphique de même que de la détermination des rapports paléogéographiques.

Dans le Bakony Méridional, la série sénonienne supérieure gît en discordance sur le complexe turonien de conglomérat et d'argile bigarrée, le Sénonien inférieur y fait défaut.

La sédimentation du Sénonien supérieur prend naissance par les gisements du groupe houiller d'eau douce. Ce sont des phases saumâtres (oligomésohalines) puis marines qui succèdent à la phase d'eau douce (Bartha, 1963).

Parallèlement à la première ingression de la mer, une formation récifale, notamment le groupe de calcaire à Hippurites-Coralliaire se dépose sur la partie élevée du territoire tectoniquement préformé.

Des ingressions et régressions peu intenses de la mer, l'oscillation de la salinité se font encore sentir dans la faune de la série, notamment dans les couches inférieures du groupe de marne calcaire à Coralliaires et Mollusques (biofaciès glauconieux), mais l'apparition des Coraux solitaires dans la partie supérieure prouve la stabilisation de la salinité.

Dans le groupe de marne à Gryphaea, l'on distingue six horizons: ceux à Clavagella, Dentalium, Exogyra, Aptyxiella, Gervilleia et Ostrea.

Le groupe de calcaire à Hippurites-Coralliaires représente un faciès hétéropique de la partie supérieure du groupe houiller, c'est-à-dire des groupes de marne argileuse à Coralliaires-Mollusques et de marne à Gryphaea (Sümeg), tandis qu'ailleurs (Ajka, Bassin de Zala) il gît directement sur la marne à Gryphaea. Les espèces de grande aire que l'on rencontre dans la faune du groupe de calcaire et de marne à Inocérames, prouvent une communication avec la haute mer.

Sur la base de leur lithofaciès et de leur faune, les formations sénoniennes de Sümeg touchent bien aux couches moyennes et supérieures de Gosau (Autriche). La faune de Hongrie contient davantage d'éléments méridionaux. La faune de Mollusques correspond au faunes sénoniennes de l'Autriche, de la France, de la Yougoslavie, de la Grèce, de la Roumanie. C'est dans les faunes d'Hippurites et de Radiolites du groupe de calcaire à Hippurites-Coralliaires que les éléments méridionaux se font le mieux valoir, notamment la plupart des éléments fauniques est surtout analogue aux faunes des calcaires à Rudistes du Midi de la France, de l'Espagne du Nord (Pyrénées), de la Grèce, de la Yougoslavie et de l'Autriche. La migration de la faune partant du Midi de la France, passant la péninsule Ibérique et l'Italie, se dirigeant vers l'Orient. Elle passait par un prolongement de la mer méditerranéenne, partie du Bassin de Zala, vers les Monts de Bakony, partie vers l'Autriche.

La sédimentation commença dans le sous-étage santonien supérieur, par la formation de la houille, puis elle continuait dans le Campanien inférieur, encore par les couches de marne calcaire à Coralliaires-Mollusques. Le groupe de calcaire à Hippurites-Coralliaire, en faciès hétéropique des formations susmentionnées, remplit le Campanien entier, dans les environs de Sümeg (à Ajka et dans le Bassin de Zala, on n'en trouve que la partie supérieure). La série sédimentaire se termine par les formations maestrichtiennes du groupe de calcaire et de marne à Inocérames.

I. Introduction

Depuis le milieu du siècle dernier jusqu'à nos jours, nombre de chercheurs se sont occupés de l'analyse stratigraphique des formations sénoniennes des Monts de Bakony, notamment HAUER (1861), HANTKEN (1875), KOCH (1871, 1875, 1878), BÖCKH (1872—1874), OPPENHEIM (1892), PAPP (1903), LÓCZY (1913), ROZLOZSNIK (1925, 1928, 1940), BARNABÁS (1937), NOSZKY (1944, 1951, 1957), DARÁNYI (1957), KOPEK (1958, 1961), VADÁSZ (1960), DUBAY (1956, 1962), MAJZON (1956, 1961).

Le nombre des ouvrages paléontologique est bien insignifiant, ils traitent, pour la plupart, la faune de Mollusques du groupe houiller: TAUSCH (1886), OPPENHEIM (1892). Dans quelques ouvrages, on trouve des descriptions des espèces de Rudistes, de Huîtres et d'Echinides: JASKÓ (1935), BARNABÁS (1937), NEUBRANDT (1949) examina les séries évolutives des Pyrgulifera. CSILLAG-TEPLÁNSZKY (1953) a décrit des espèces de Gastéropodes dans son travail de diplôme qui n'a pas été imprimé.

C'est au cours des derniers dix ans que l'on publie des monographies traitant de différents groupes fauniques des Monts de Bakony, notamment GÉCZY (1954, Cyclolites), KOLOSVÁRY (1954, Coralliaires), SZÖRÉNYI (1955, Échinides).

Il y a quelques années qu'on a commencé la révision complexe du Sénonien de la Hongrie, par des examens palynologiques (GÓCZÁN 1961, 1963), micropaléontologiques (SIDÓ 1962, 1963), malacologiques (des faunes marines), (BENKŐ-CZABALAY, 1961, 1962, 1963/a, 1964/a, 1964/b, 1964/d, 1965), malacologiques (des faunes d'eau douce et saumâtres, groupe houiller) (BARTHA 1963), sédimentologiques et lithologiques (FAZEKAS, G. 1961, OSVÁTH 1962, 1963) et tectoniques (KOPEK).

En ce qui suit, notre point de départ sera l'examen paléontologique détaillé du Sénonien des Monts de Bakony, mais en ce qui concerne le dépouillement stratigraphique et la détermination des rapports fauniques et paléogéographiques, nous prenons également en considération les faunes des autres formations sénoniennes de la Hongrie (Bakony Septentrional, Monts de Bükk, Bassin de Zala). Les matériaux des localités fossilifères du Sénonien que l'on vient d'énumérer ne se prêtaient point à une analyse stratigraphique subtile, vu que l'on n'avait obtenu que des échantillons de mauvaise conservation, prélevés de forages (Bassin de Zala); ailleurs (Monts de Bükk) la série montrait des lacunes; ou bien le moyen ne se trouvait pas pour une récolte systématique [couche par couche (Monts de Bakony Nord)].

II. Sédimentation

Dans les Monts de Bakony, la série du Sénonien supérieur gît en discordance sur le complexe de conglomérat et d'argile bigarrée du *Turonien*; les formations du Sénonien inférieur y font défaut.

La sédimentation du Sénonien supérieur commence par les gisements de houille d'eau douce du *groupe houiller*; la partie inférieure dont la faune des couches de grès et d'argile sableuse contient encore des éléments terrestres, mais pour la plupart elle consiste en formations d'eau douce. Le socle du bassin s'était affaissé graduellement sur la partie élevée du terrain de Sümeg tectoniquement préformé; les gisements de houille se trouvent dénudés par l'ingression marine qui avait remanié même une certaine partie du calcaire haut-riverain sous-jacent, en produisant des *couches de conglomérat*. L'ingression de la mer avait produit un changement même dans la faune de Mollusques du *groupe houiller :* selon BARTHA (1963), les formes sensibles même à une moindre augmentation de salinité disparaissent dans la phase *oligohaline*. Dans la phase *mésohaline*, on trouve, à côté de Pyrgulifera glabre, à coquille lisse, des formes ornées de Pyrgulifera. Par suite de secousses telluriques la mer gagne du terrain, la salinité augmente: dans la *phase marine*, la plupart de la faune consiste en formes *brachyhalines*.

A Sümeg, à la partie élevée du territoire, les formations des faciès *récifal* et *subrécifal* (groupes de calcaires à Hippurites) gisent en discordance sur les couches de conglomérat sénonien, c'est l'aspect *caudiobioherme* qui caractérise ce faciès où des calcaires récifaux à lentilles et des bancs s'alternent avec les associations fauniques des couches marneuses et argileuses; dans cette série les *biohermes* sont bien fréquents.

Parallèlement à la dessalure très modérée *(phase brachyhaline)*, observable dans la partie supérieure du groupe houiller, des associations fauniques se sont développées dans les bancs inférieurs du calcaire à Hippurites qui étaient également en corrélation avec une légère diminution de salinité *(couches* à *Acteonella)*. Plus tard, l'oscillation de la salinité est à remarquer dans la partie inférieure du *groupe de marne* à *Coralliaires et Mollusques* laissant deviner ses traces même dans la faune du calcaire à Hippurites.

Le calcaire à Hippurites signale le bord des sédiments du bassin, tout en formant une digue contre la mer affluante ne cédant que graduellement à la transgression.

De légères ingressions et régressions de la mer, et l'oscillation de la salinité sont encore observable dans l'horizon inférieur du *groupe de marne argileuse* à *Coralliaires-Mollusques*. C'est la prépondérance des couches de marne argileuse qui est la caractéristique de ce groupe; la faune consiste en Gastéropodes et Lamellibranches, très riches en espèces et individus. La faune associée contient beaucoup de restes de Foraminifères, d'Ostracodes, de coraux solitaires (Cyclolites), de Bryozoaires, de Cirripèdes à tige et de traces d'éponges perforantes.

Le groupe de marne argileuse à Coralliaires-Mollusques se divise, sur la base de la faune de Mollusques, en deux horizons; les changements fauniques bien brusques nous permettent d'établir, dans ceux-là, de divers biofaciès et de phases.

1. *L'horizon* à *Gastéropodes-Pecten-Cardium-Coralliaires* se divise sur la base de la faune bien riche de Gastéropodes, en deux biofaciès. Celui inférieur (glauconieux) contient, pour la plupart de Glauconies, auprès desquelles on observe des espèces de Lamellibranches caractérisant surtout des couches saumâtres, notamment Cardium ottoi Geinitz, Limopsis calvus Zittel, Plicatula aspera Zittel et Cyrena solitaria Zittel. A en juger sur les formes actuelles des éponges perforantes (Clionia vastifica Volz) dont les traces se présentent en abondance dans les Glauconies, celles-ci pouvaient supporter le changement même bien important de la salinité de la mer. Les couches de marne argileuse, peu sableuse, à grain fin, jaune, se sont déposées dans la zone littorale relativement abritée de la houle (secteur O).

La faune du *biofaciès supérieur (à Cerithium ou Pirenella)* consiste pour la plupart en espèces euryhalines (Pirenella, Tympanotones); la partie moins nombreuse de la faune représente des espèces qui se rencontrent dans les formations saumâtres (Angaria, Tectus), Une partie moins considérable des espèces de Gastéropodes vivaient enfoncées dans la vase du fond. Dans le secteur inférieur (N) se présentent les Lamellibranches euryhalines. Ces espèces-ci deviennent dominantes dans le secteur M, puis au fur et à mesure que la salinité augmente, les formes marines apparaissent (Astarte similis Münster) et les formes d'eau saumâtre disparaissent; la présence des coraux solitaires dans la faune associée prouve la stabilisation de la salinité. Aux endroits où cette formation s'intercale parmi les membres du groupe de calcaire à Hippurites, on trouve beaucoup de restes de carapaces de Cirripèdes à tiges, menues, sédentaires; c'était par ces tiges qu'ils se fixaient à de diverses agglomérations du faciès récifal. Les espèces actuelles se trouvent pour la plupart dans les zones pélagiques, mais on en connaît quelques unes dans les zones littorales de l'Europe. A en juger sur les autres éléments de la faune, la profondeur de la mer ne dépassait pas celle de la zone de marée, mais il est bien probable que des changements temporaires de la profondeur aboutissaient de temps en temps au dépérissement de l'un ou de l'autre des groupes.

2. *L'horizon à Lamellibranches* (Nucula-Corbula) a été divisé en six secteurs (L, K, J, I, H, G) sur la base de la dominance des espèces de Lamellibranches. Dans le secteur inférieur (L) la plupart des espèces représentent des formes exigeant une salinité normale (Nucula, Corbula, Astarte, Lima), dans la faune y associée le nombre des coraux solitaires augmente. La substance des roches est plus marneuse et calcaire que dans le groupe sous-jacent. Plus haut, dans le *secteur* K, le nombre des individus des espèces du genre Astarte augmente parallèlement au nombre d'individus des coraux solitaires; cependant, sous l'action de l'augmentation de la teneur en sulfure de fer de la mer et sous celle de l'affaissement du fond marin, le nombre des espèces: Corbula, Nucula et Lima va diminuant. Dans le *secteur* J, bien que le nombre des espèces exigent une salinité normale les espèces euryhalines passent également au premier

plan. Quand les expèces Lopha semiplana (Sow.) et Crassatella macrodonta var. sulcifera Zittel, caractéristiques du fond plus profond et plus tranquille de la mer, les espèces de Nucula et de Cyrena, signalant la zone littorale, disparaissent. Au fur et à mesure que le nombre des formes euryhalines (Panopea, Meretrix) augmente, celui des coraux solitaires diminue. Les formes vasicoles, en partie enfoncées dans la vase, deviennent de plus en plus nombreuses.

Dans le *secteur* I, y suivant, les espèces de Modiola sont remplacées par des Pholadomya, le nombre des individus des espèces d'Astarte et de Corbula augmente, cela concerne, en général, les espèces qui n'étaient pas sensibles à la diminution du mouvement et de l'aération de l'eau de la mer.

Dans le *secteur* H, on observe déjà les espèces caractéristiques du fond tranquille et vaseux de la mer: Modiola sphaeonoides Defr., Cucullaea austriaca Zittel. Auprès des coraux solitaires, bien nombreux, on trouve des espèces de Gervilleia à coque mince. Dans le *secteur supérieur* (G), mal aérée, à haute teneur en substance organique de la mer, des conditions d'existence très défavorables se sont produites pour les Coralliaires. Les espèces de Clavagella, associées aux Pholadomya, font ici leur apparition supportant très bien les conditions d'existence données.

En outre des changements de conditions de lithofaciès et de biofaciès: l'importance du facteur du temps augmente également dans ces deux secteurs-ci (H, G), puisqu'on y observe l'apparition des espèces qui deviendront dominantes dans le sous-étage campanien supérieur, notamment: Pholadomya granulosa Zittel, Modiola sphaenoides Zittel.

Groupe de marne à Gryphaea

Les formations du groupe de marne à Gryphaea gisent en concordance immédiate et sans lacune sur le groupe de marne argileuse à Coralliaires et Mollusques. En ce qui concerne la faune de ce groupe, dans les horizons inférieurs (secteurs F à C) c'est l'abondance des Clavagella et Scaphopoda qui en est caractéristique, tandis que dans les horizons supérieurs (secteurs C à A) ce sont les espèces de Modiola, Gervilleia et Ostrea qui deviennent dominantes. Dans les horizons supérieurs du groupe il arrive que l'une ou l'autre des espèces apparaissent en masse, presque en quantité constituant de roche (horizons à Exogyra, Aptyxiella).

Des formations de marne et de marne calcaire s'alternent, peu à peu la marne calcaire devient prépondérante. Sur la base des changements fauniques, on a distingué six horizons dans la série à Gryphaea, notamment les horizons à *Clavagella*, *Dentalium*, *Exogyra*, *Aptyxiella*, *Gervilleia* et *Ostrea*. La faune des deux horizons supérieurs montre bien qu'une communication s'est établie entre le golfe clos et la haute mer: des espèces de plus en plus vaste aire horizontale y apparaissent.

Dans le secteur inférieur (à Clavagella), dans la zone sublittorale riche en substance organique, mal aérée, des formes, pour la plupart enfoncées dans la vase, vivaient dans le fond vaseux. Parallèlement au nombre d'individus relativement grand des Clavagella, c'est le nombre d'individus de Nucula concinna Sow. et Cyrena solitaria Zittel qui augmente. Les Gastéropodes sont des espèces exigeant une salinité normale (Ampullina, Piestochilus).

Dans l'*horizon* à *Dentalium* les sédiments argileux deviennent de plus en plus sableux. Le mouvement de la mer est devenu de plus en plus intense, l'échange d'oxygène s'est accéléré, les espèces de Fusus, Corbula et Tellina disparaissent de la faune, les espèces de Nucula et de Cyrena deviennent plus nombreuses, les Scaphopoda se présentent aussi en nombre plus considérable (secteur E). Dans le secteur moyen (D) les espèces de Modiola et Cucullaea font défaut. Dans le secteur supérieur (C), la roche consiste en marne calcaire; les espèces dominantes étant Tellina stoliczkai Zittel et Corbula angustata Sow.

Dans le faciès à vase calcaire de l'*horizon à Exogyra*, c'est l'espèce Exogyra matheroniana d'Orb. qui se présente en quantité constituant de roche, associée à quelques Ostrea et Gervilleia à coquille mince. C'est le faciès de vase calcaire de la zone néritique qui s'y est développé; des formes à coquille mince apparaissaient, ce qui prouve la salinité normale et l'échange rythmique de l'eau de la mer.

Dans l'*horizon* à *Aptyxiella*, l'appauvrissement en espèces de la faune continue, ce n'est que l'espèce Aptyxiella flexuosa, de petite taille, qui s'y présente en quantité constituant de roche.

Dans l'*horizon à Gervilleia* c'est Gervilleia solenoides Defr. qui est dominant, à côté des espèces Limopsis sp., Ostrea sp., et Gryphaea vesicularis Lam. Cette association faunique caractérisant le faciès à vase calcaire de la zone néritique; la disposition des coquilles par endroit en lumachelle dans la matière de la roche, tout indique l'oscillation du fond et les intensifications temporaires du mouvement de la mer.

Dans les couches dures de marne calcaire de *l'horizon* à *Ostrea*, les Gervilleia disparaissent; l'on n'y trouve que de fragments des espèces d'Ostrea. Par endroit, les plans de stratification sont couverts de bandes d'écailles de poisson, les Ammonites et les Échinides manquent dans cet horizon.

Groupe de calcaire à Hippurites-Coralliaires

Ce groupe présente une riche variété des facies récifaux et subrécifaux, avec l'alternance des bancs à Rudistes, des formations marneuses, de marne calcaire, par endroit argileuse.

A Sümeg, les calcaires à Exogyra gisent en discordance sur les couches conglomératiques, dans ceux-là les Exogyra se présentent en quantité constituant de roche. Le faciès sublittoral est représenté par des sédiments pro-

duits dans une zone fort houleuse où la faune encaissée dans la roche prend un caractère de remaniement dans l'eau.

Au fur et à mesure que le mouvement de la mer devenait plus intense, le rythme de l'échange d'oxygène s'accélérait également: dans *la couche de grès à grain fin*, on trouve une faune de Nerinea de grande taille. La présence des Nérinées à coquille épaisse prouve que l'échange d'oxygène devenait plus intense, la température de l'eau plus élevée et la précipitation de chaux s'intensifiait. Les expèces d'Acteonelle se trouvant dans *les bancs de calcaire* au-dessus des couches à Nérinée, indiquent une légère déssalure de la mer. Ce cycle sédimentaire se termine par un autre banc à *lumachelle*. Le *biofaciès à Échinides* est tout à fait différent des faunes des couches susmentionnées; il s'est développé dans une partie tranquille, détachée du récif. Dans la série gisant sur le *banc à Échinides*, des bancs de calcaire, des couches de marne grise feuilletée s'alternent avec des *couches intercalées à Algues*, *Huîtres*, *Coralliaires*, *Trigonies*. Dans les couches de calcaire, on observe une faune de Rudistes, caractéristique du faciès récifal; dans les couches marneuses celles-là se remplacent par des espèces isolées, aussi trouve-t-on, bien souvent, dans ces formations-ci, des Rudistes remaniés de la faune du faciès récifal.

Dans ce rythme de la faune et de la sédimentation on peut bien reconnaître les facteurs écologiques qui ont mis fin à la fonction de certains biofaciès (bioherme ou récif) et les menaient à la destruction. P. e. la végétation d'algues ayant couvert la colonie des Rudistes, diminuait puis arrêta la circulation de l'eau, ceci empêchant la nutrition des individus de la colonie. Ou bien, dans d'autres cas, le mouvement de la mer redevenant intense, l'eau plus limpide et claire, amena des conditions d'existence *permettant l'évolution* d'un nouveau récif de Rudistes.

Ce cycle sédimentaire s'achève par une formation de calcaire récifal renfermant des Hippurites de grande taille, avec des intercalations de *calcaire à Exogyra* dans l'horizon supérieur. D'après des observations toutes récentes (communication verbale de Góczán, F.) c'est sur ce banc que se déposent les soi-disant couches de Hárskút qui correspondent à l'horizon inférieur du groupe de marne calcaire à Coralliaires et Mollusques. Dans la faune associée, on trouve des traces d'éponges perforantes (Clionia vastifica Volz) caractéristiques des faciès récifaux et subrécifaux et des restes de Cirripèdes à tige.

Dans les bancs supérieurs du groupe de calcaire à Hippurites (carrière de Gerinc), ce sont les intercalations de *marne argileuse* et *d'argile à Exogyra*, *de Cyclolites*, et *de Lamellibranches* qui s'alternent avec les *bancs* de *calcaire*; se fondant sur les analyses palynologiques et malacologiques, ces couches d'argile et de marne argileuse peuvent être mises en corrélation avec certains horizons du *groupe* de *marne à Gryphaea*. Partant du bas en haut, le nombre des couches d'argile et de marne argileuse diminue dans le groupe, tandis que la richesse en espèces d'Hippurites formant des colonies va augmentant,

celles-ci apparaissent par endroit avec des colonies intercalées de Radiolites ou, plus rarement, associées.

En ce qui concerne son faciès, le groupe de calcaire à Hippurites représente un *caudiobioherme*, les couches marneuses s'alternent avec des calcaires récifaux en lentilles ou en bancs, par endroit — s'amincissant en forme de coin — elles sont en contact avec les formations subrécifales, littorales ou néritiques, ou bien présentent une transition graduelle de faciès en faciès.

III. Dépouillement stratigraphique, rapports fauniques, conditions paléogéographiques

Dans le Bakony Méridional, la sédimentation du Crétacé supérieur commence par le complexe d'argile et de conglomérat continentaux que l'on considère comme turonien, respectivement par le groupe houiller, d'eau douce-saumâtre du Santonien supérieur, qui gît en discordance sur ce complexe-là. A Ajka, on trouve même de la bauxite parmi les couches d'argile bigarrée (Darányi 1957); ces formations-ci peuvent être mises en corrélation — en ce qui concerne l'âge — avec la bauxite turonienne examinée en Autriche (environs de Grünbach et Neue Welt) par Plöchinger et coll. 1961, p. 406, Fig. 8).

Sur la base des faciès faunique et géologique, le *groupe houiller* peut être identifié avec le groupe houiller du *Santonien supérieur-Campanien inférieur* de Neue Welt en Autriche. La riche faune de Pyrgulifera se trouve également das les couches intercalées parmi les gisements de houille d'âge analogue de l'Autriche et de la Yougoslavie; dans les environs de Grünbach, en Autriche, l'horizon vraiment productif du groupe houiller manque, toutefois dans le groupe saumâtre de régression susjacent, Oberhauser a trouvé les mêmes espèces de Foraminifères que Sidó a récoltées dans les couches supérieures du groupe houiller de Sümeg. Des formations d'âge et des faciès analogues sont connus — par endroits et bribes seulement — en Tchécoslovaquie (Bradlo), en France, en Grèce, en Yougoslavie et en Roumanie (Borod).

La riche faune de Glauconies du *groupe de marne argileuse à Coralliaires et Mollusques* est caractéristique du sous-étage campanien; l'on y trouve des espèces fréquentes en partie dans les couches du Campanien inférieur de Plan d'Aups (France) et de la Roumanie (Transylvanie) *Glauconia renauxiana d'Orb.*) en partie dans les sous-étages campanien et maestrichtien de la Yougoslavie et dans le Campanien de l'Autriche *(Glauconia coquandiana kefersteini Münster)*. Petkovič (1954), en examinant l'importance stratigraphique de cette espèce-ci, a établi qu'elle atteignait sa dominance dans les couches campaniennes; selon Cirič (1952) cette espèce était caractéristique des formations saumâtres du sous-étage *campanien inférieur*.

Les petites espèces de Pirenella qui apparaissent en masse dans le biofaciès à Cerithium (Pirenella) marquent plutôt le faciès. Les espèces *Pirenella münsteri (Keferstein)* et *Pirenella hoeninghausi (Keferstein)* se présentent également dans les couches de Gosau moyen *(Santonien supérieur-Campanien)* de l'Autriche, dans le Campanien inférieur de la Roumanie (couches à Cerithium en Transylvanie) et dans le Santonien supérieur de la France (Sougraigne). *Aptyxiella (Acroptyxis) flexuosa (Sow.) Tiedt et Aptyxiella (Acroptyxis) gracilis (Münster) Tiedt* sont bien fréquents dans les couches campaniennes de Gosau, *Otostoma zekeliana (Stol.)*, *Neritopsis goldfussi (Münster)* dans les formations campaniennes de l'Autriche, de l'Inde, de la Yougoslavie et de l'Allemagne. Les autres espèces se présentent également dans les couches du Santonien supérieur et du Campanien inférieur: en Autriche, Grèce et Yougoslavie *[Tanaliopsis spinigera Zekeli, Helicaulax granulata (Sow.) et Ampullina (Pseudamaura) bulbiformis (Sow.)]*.

La faune de ces couches est en connexion étroite avec les faunes d'âge et de faciès analogues de l'Autriche, de la Roumanie et de la Yougoslavie; 24 espèces de Gastéropodes sont identiques avec la faune de Gosau, 6 espèces avec celles de Plan d'Aups, 11 espèces avec celles de Roumanie (Transylvanie, Borod), tandis que 3 espèces de Glauconie des formations d'eau douce de l'Allemagne sont identiques avec les nôtres. La faune de Gastéropodes montre — en pourcentage inférieur — certaines analogies avec les espèces (Glauconia, Ampullina) du *Campanien inférieur* de la Grèce et de la Yougoslavie.

Sur la base de la faune énumérée, nos couches, de même que les formations d'eau douce de Plan d'Aups et du Harz datent du *Campanien inférieur*. Dans les couches de Gosau des Alpes, la plupart des Gastéropodes se trouvent dans le même horizon, notamment dans la marne imperméable gisant sur le calcaire à Hippurites du *Santonien supérieur*, voilà l'unique *formation houillère de Gosau*. On peut bien suivre les traces de ces formations dans le Tyrol, dans la vallée Ache de Brandenberg, puis elles se prolongent par GLEISL pour être retrouvées près du Sonnwendjoch, St. Gilgen et St. Wolfgang à l'Aubersee où elles gisent également sur le Santonien supérieur; à St. Wolfgang, le long du chemin conduisant au Schwarzensee on peut bien suivre les formations campaniennes inférieures au bord sud du Bassin de Gosau, à Traunwand, Schottau et Horneck, au NE vers le Traunsee, puis plus loin vers le Sud jusqu'à Hieflau, Gams, Plahberg et Königsbaueralp, à Lassau. C'est à Grünbach qu'elles forment l'unique gisement de houille exploitable qui se présente à Neue Welt dans une zone tectonique bien troublée, son dernier affleurement se trouvant à Einöd, près de Vienne. La plupart des espèces de Gastéropodes du Bakony sont identifiables avec celles récoltées dans les couches du *Campanien inférieur* de l'Autriche.

On connaît de couches de toit houiller analogues en Yougoslavie; la faune du biofaciès glauconieux est identique avec la faune des couches glauco-

nieuses de celles-là. En Roumanie (Borod), on retrouve le même faciès, puis vers le SE, c'est en Grèce que l'on observe une formation analogue, d'eau saumâtre, régressive, du *Campanien inférieur*. Vers le NW, le dernier prolongement des formations de Gosau se trouve en Tchécoslovaquie (Bradlo) où l'on ne connaît que de lambeaux du groupe houiller. Au SE, dans les Monts de Bükk, les formations houillères et les couches de toit ne se sont pas développées. Au SE, en France, dans la faune des formations régressives du *Campanien inférieur* de Plan d'Aups, les espèces de Glauconie sont identiques, ce qui s'explique probablement par une analogie de faciès, car aucun rapport faunique n'est démontrable avec ce terrain-ci. En France, la régression dure plus longtemps, par la suite d'un processus de dessalure, les formations saumâtres sont remplacées par des formations d'eau douce, fluviatiles, qui remplissent même le *Campanien* et le *Maestrichtien*. En Espagne (Pyrénées) Bélesta (Ariège), le *Campanien* est représenté par *le calcaire* à *Hippurites*, avec des *intercalations d'argile bleue et de marne*, au S du récif à Rudistes on trouve la lignite sénonienne qui, selon VILLALTE (1953) soit *un facies hétéropique* du calcaire à Hippurites. Parmi les espèces de la faune mentionnée par VILLALTE, 14 sont identiques avec celles de Gosau, comme p. e. Glauconia coquandiana kefersteini Münster, Haustator fittonianus (Sow.), etc. Les sédiments en partie lagunaires sont remplacés par des formations marines et, en Ariège, la transgression complète est indiquée par *le calcaire à Hippurites* du *Campanien supérieur*. En ce qui concerne la faune et le faciès, cette série présente beaucoup d'analogies avec la faune de Rudistes que l'on va traiter plus bas.

Dans la faune de Lamellibranches de l'horizon supérieur du *groupe de marne argileuse à Coralliaires et Mollusques* se présentent déjà des espèces qui deviennent dominantes dans le sous-étage campanien supérieur (Pholadomya granulosa Zittel, Modiola sphaenoides Defr.), mais les autres espèces (Astarte similis Münster, Lopha semiplana (Lam.) Pecten laevis Nilsson) ne se trouvent pas dans les formations supérieures au *Campanien inférieur*. En outre, la faune de Cyclolites se retrouve partout dans le *Campanien inférieur*, dans les couches de toit du gisement houiller ou dans les sédiments saumâtres régressifs de l'Autriche, de la France (Plan d'Aups), de la Roumanie (Borod), de la Yougoslavie et de la Grèce.

La faune de la *marne à Gryphaea* se distingue nettement de celle du groupe précédent. Les espèces Exogyra matheronia d'Orb., Gryphaea vesicularis Lam., se présentent dans le *Campanien supérieur* en France, en Yougoslavie, en Autriche et en URSS (Crimée, Caucase), cette espèce-ci devenant dominante dans le *Maestrichtien*. Les espèces Pholadomya granulosa Zittel, Gervilleia solenoïdes Defr., Dentalium hexapleura Zittel et Dentalium nudum Zittel sont caractéristiques des formations du *Campanien supérieur* de l'Allemagne et de l'URSS. Sur la base de l'association faunique caractéristique, nous considérons le groupe de marne à Gryphaea comme Campanien supérieur;

dans ce groupe sédimentaire les espèces caractéristiques du Sénonien des territoires situés en dehors du géosynclinal méditerranéen deviennent de plus en plus nombreuses.

Le *calcaire à Hippurites* qui est, à Sümeg un faciès hétéropique de la marne à Coralliaires et Mollusques et du groupe de marne à Gryphaea et, en partie, même des couches de toit du groupe houiller, se présente ailleurs en faciès différents. Dans le Bakony Méridional, à Ajka, cette formation gît sur la marne à Gryphaea dans une épaisseur de 20 m, et tout récemment, sur la base des observation des géologues miniers, on en est arrivé à la conclusion (KOZMA, 1964) que le calcaire à Hippurites représente ici aussi — par endroit — un faciès hétéropique d'autres formations. Dans le Bakony Septentrional, on trouve cette formation en bancs, parmi les couches marneuses; d'après les observations de KOPEK, la série du forage de Magyarpolány 1. prouve le même fait, par conséquent il est bien probable que le calcaire à Hippurites est un faciès hétéropique de la marne à Gryphaea, aussi au territoire du N. Puisque les formations du groupe houiller est celles du groupe de marne argileuse à Coralliaires et Mollusques ne se sont développées qu'en partie ou d'une manière défectueuse, il faut encore continuer les recherches pour pouvoir résoudre le problème et savoir quelles sont les séries où — dans le territoire du N — *le calcaire à Hippurites* peut-il être considéré comme faciès hétéropique, en dehors du groupe à Gryphaea.

A notre avis, *le calcaire* à *Hippurites d'Ajka* ne représente que la partie supérieure de celui de Sümeg, aussi peut-on s'imaginer qu'il ne soit dans le Bakony *Septentrional* que de faciès hétéropiques à Gryphaea, et que ce n'est que la partie supérieure de la série de Calcaire qui y est représentée. Le calcaire à Rudistes de Nagylengyel (Bassin de Zala) gisant sur la série à Gryphaea, peut être mis en corrélation avec la partie supérieure du groupe de *calcaire à Hippurites du Bakony méridional.* La corrélation entre les deux calcaires est rendue difficile à cause de la puissance différente du calcaire du Bassin de Zala et des lacunes de nos connaissances sur la faune; à notre avis il s'agit du calcaire campanien dont les bancs supérieurs sont éventuellement en corrélation avec le calcaire à Orbitoïdes (Lepidocyclina) de Sümeg.

Les faunes riches et variées d'Hippurites et de Radiolites du *groupe de calcaire à Hippurites et Coralliaires* indique des rapports avec les faunes du géosynclinal méditerranéen. Les espèces de la faune se présentent moitié Hippurites, moitié Radiolites (8—8).

Une partie des espèces de la faune d'Hippurites se présente et dans le Santonien supérieur et dans le Campanien inférieur, pour la plupart dans des séries où il est bien difficile de tracer la limite entre les deux sous-étages en se basant sur la faune de Rudistes; en général c'est la répartition verticale plus considérable des espèces qui en est caractéristique. Dans *les horizons inférieurs* du groupe de calcaire les espèces Hippurites (Vaccinites) carinthiacus Redlich

et Hippurites (Vaccinites) oppeli santoniensis Kühn sont bien fréquentes et abondantes; elles sont caractéristiques des calcaires et du Santonien supérieur et du Campanien inférieur.

Ces deux espèces-là sont bien connues en Autriche, dans le récif principal du Santonien supérieur, notamment à Untersberg dans les couches du *Campanien inférieur*, à Kainach dans *les couches campaniennes*. Les espèces Hippurites (Vaccinites) cornuvaccinum Bronn et Hippurites (Vaccinites) atheniensis Ktenach sont caractéristiques du *Campanien inférieur* de la Grèce (Livadie-Talanti-Pélagonie-Ptoon-Chaeromaea) en Yugoslavie (Istrie) elles sont connues dans les calcaires récifaux *santoniens supérieurs — campaniens inférieurs*, puis en Autriche (Kainach) dans celui du Campanien. La plupart de ces espèces-là sont encore à rencontrer au Sud du Bakony: Dalmatie-Istrie, puis au SE: Grèce, au SW: Autriche (Kainach), puis en Italie (Santa Croce, Sesana, Nabresian).

L'espèce Hippurites (Vaccinites) sulcatus Defr. est bien fréquente, en outre des territoires que l'on vient de mentionner, aussi dans le Midi de la France (Pyrénées), en Tchécoslovaquie et en Roumanie (Mte Apuseni), dans les formations du *Santonien supérieur et du Campanien inférieur*; cette même espèce et Hippurites (Orbigny) sulcatoïdes Douv. et Hippurites (Vaccinites) archiaci Munier-Chalmas y associées sont caractéristiques des calcaires à Rudistes campaniens des Pyrénées. Dans les Mtes Bélesta (Ariège) et en Catalogne cette association faunique représente le *Campanien supérieur*; en Grèce les calcaires à Rudistes renferment les mèmes espèces (Sornay 1961); dans la zone pélagonienne des Radiolites s'associent à H. (V.) archiaci Munier-Chalmas, on observe bien des intercalations de calcaire à algues dans la série: ces couches-ci sont *Campaniennes inférieures*, tandis que là où Hippurites (Vaccinites) oppeli Douvillé apparaît, il s'agit déjà du *Campanien supérieur*.

Hippurites (Vaccinites) archiaci Munier-Chalmas est généralement caractéristique du *Campanien supérieur*, selon Douvillé cette espèce est connue dans le Midi de la France à 100 m au-dessous du Maestrichtien et à 200 m au-dessus de l'horizon de Lima marticensis, c'est-à-dire dans des couches bien élevées du Campanien. H. (V.) archiaci Munier-Chalmas est fréquent en Roumanie, en Grèce, dans le Midi de la France, dans le Nord de l'Espagne, étant partout caractéristique du *sous-étage campanien*.

Hippurites (Orbignya) colliciatus Woodward est bien répandu en Autriche, en Grèce, en Yougoslavie, en France, dans le Nord de l'Espagne, en Roumanie; cette espèce se présente dans les couches du *Santonien supérieur* et du *Campanien inférieur* de la France (Montagne des Cornes) de même que dans le *Campanien inférieur et supérieur* de l'Autriche (Hieflau, Gams).

La faune de Radiolites du Bakony est en connexion étroite avec les faunes des faciès à Radiolites des Pyrénées et de la Grèce. C'est Radiolite angeoïdes Picot de Laperouise qui a la plus vaste aire horizontale parmi les

espèces de cette faune, on le trouve dans les sous-étages *Santonien supérieur* et *campanien inférieur* de l'Autriche (Gosau, Untersberg, dans les environs de Salzburg), dans les formations du *Santonien supérieur* (Pont du Fahs, La Jouane à Sougraigne, Roo de Camps) et du *Campanien inférieur* (Montagne de Corne) de la France, dans le *Santonein supérieur* et *Campanien inférieur* de la Grèce (près de Pylos, Poros, Othyris), dans les couches du *Santonien supérieur* et *Campanien inférieur* de la Yougoslavie (Istrie, Dalmatie), de la Perse, de l'Asie mineure, de la Tunisie et de l'Algérie. En Yougoslavie, cette espèce est connue des couches du *Santonien supérieur* (Sovać, Krst, Pochita), mais associée à H. (V.) oppeli Douv. et H.(V.) gosaviensis Douv., elle appartient déjà au *sous-étage campanien.*

Radiolites styriacus (Zittel) Toucas, Radiolites subtoucasi Toucas et Radiolites nouleti Bayle sont fréquents dans les calcaires à Rudistes du *Campanien supérieur* d'Ariège, avec l'espèce H.(V.) archiaci Munier-Chalmas. En Autriche (Untersberg) les formations où cette espèce apparaît avec Hippurites (Vaccinites) cornuvaccinum Bronn et Hippurites (Vaccinites) sulcatus Douv. représentent le *Campanien inférieur* — respectivement, à St. Gallen, Hieflau, Plahberg — le *Campanien.*

Radiolites cf. matheroni Toucas, Radiolites cf. subradiosus Toucas et Radiolites aff. albonensis Toucas n'ont que chacun un représentant dans la faune, par conséquent il a été impossible de les déterminer d'une manière plus précise. Les deux premières de ces espèces-là sont fréquentes dans les calcaires à Hippurites du Santonien inférieur et supérieur; selon ASTRE, (1954), Radiolites matheroni peut éventuellement se présenter dans le Campanien inférieur, tandis que R . albonensis, autant qu'on en sache actuellement, est connu dans le Maestrichtien.

Dans le Santonien supérieur, une communication directe s'établissait au territoire de la France entre les parties méditerranéenne et boréale de la mer, en conséquence de quoi les Rudistes se retiraient vers le S. En Provence, le dernier faciès récifal se développa dans le Santonien supérieur, également dans la vallée du Rhône, tandis que dans les Corbières et en Ariège ce faciès se présente dans le Campanien inférieur et supérieur. Dans le Bassin d'Aquitaine et dans les Pyrénées occidentales, on trouve encore des faciès à Rudistes dans le Maestrichtien

Dans les Corbières du S, les calcaires à Hippurites commencent à Laspinouse, voilà la base de la transgression aturienne qui se prolonge vers le W dans les Montagnes Cornes. L'émersion datait du Campanien inférieur, car les formes campaniennes supérieures des Montagnes Cornes ne se retrouvent pas dans les Corbières où les mouvements santoniens supérieur de l'écorce terrestre ont produit de golfes, du N, le long des Pyrénées, par Camps vers le W. Les calcaires à Rudistes se sont déposés avant la fin du Campanien inférieur, tandis que le sable D'Alt se produisit à la fin du Campanien.

La ligne de migration de la faune part du Midi de la France, allant par l'Espagne, l'Afrique du Nord, l'Italie vers l'Istrie; on la peut suivre partie par la Serbie vers la Grèce et l'Asie Mineure, partie vers le Nord: l'Autriche, la Hongrie, la Roumanie. La faune de Rudistes qui se retire graduellement des territoires occidentaux; avance au N de la Dalmatie; le calcaire récifal se développe dans le Santonien supérieur de l'Autriche; de l'Istrie et de la Serbie, par endroit la formation de récif continue même dans le Campanien inférieur (Autriche, Istrie, Grèce, Roumanie); en Autriche, Oberhauser a démontré l'existence du calcaire récifal campanien inférieur, à côté de l'horizon à Hippurites du Campanien supérieur, au NW de Graz (Hieflau). Le calcaire à Hippurites du Campanien supérieur gît transgressivement sur la série d'eau douce. En Grèce, dans la zone de Vardar et dans la pélagonienne, on a également pu distinguer les récifs du *Campanien inférieur* avec ceux du *Campanien supérieur* (Sornay 1961).

Sur la ligne de Dalmatie, Serbie, Grèce, il n'y a pas eu de communication avec la partie boréale de la mer, c'est ici que les faciès récifaux avancent le plus au N (Tchécoslovaquie).

Dans ce secteur géosynclinal, les calcaires récifaux se développaient en trois cycles, dans le Sénonien supérieur, notamment: le récif principal du Santonien supérieur qui se prolonge par endroit dans le Campanien inférieur; les calcaires à Rudistes se distinguent nettement du Campanien inférieur; et la série qui remplit même le Campanien supérieur.

En ce qui concerne l'identification de la faune de Rudistes, il est bien apparent que l'aire horizontale des Hippurites est relativement plus importante que celles de Radiolites qui sont plutôt liés aux parties géosynclinales du S. (Pyrénées, Yougoslavie, Grèce et Hongrie). La faune du Bakony, avec ses Radiolites, se rattache étroitement à la faune des calcaires récifaux campaniens des Pyrénées, le pourcentage important des Hippurites indique le même fait. Vers le W, il n'a pas eu de communication directe avec le territoire de l'Autriche: ce n'est qu'une partie relativement peu considérable des espèces qui est identique; vers l'E, dans la faune de Roumanie (Mte Apuseni) on trouve davantage de formes communes, mais on constate quelques différences de faciès. Vers le S, notre faune est en connexion avec les faunes des calcaires du Campanien inférieur de l'Istrie et de la Dalmatie, des calcaires récifaux de la Serbie, et on trouve beaucoup d'analogies fauniques, cénologiques et faciologiques avec les calcaires à Rudistes du même âge de la Grèce (zones Vardar et pélagonienne).

Selon Kühn, (1947), il est presque impossible d'établir la corrélation entre les divers horizons des calcaires à Rudistes du territoire méditerranéen et les quatre horizons à Hippurites de *l'Autriche*. Il est probable que la transgression campanienne se manifestait aux divers territoires par un certain déphasage, par conséquent la formation des récifs ne commençait pas à la

fois, mais selon les conditions locales. Les différences ou l'identité des faunes des calcaires récifaux s'expliquent par le fait qu'il n'y avait pas toujours de communication directe entre ces territoires, la présence des espèces identiques est dûe à l'identité éventuelle de faciès.

Le *groupe de marne et de calcaire à Inocérames* représente le *sous-étage maestrichtien*, membre le plus élevé des formations sénoniennes du Bakony. Sur la base de la faune d'Inocérames, on y distingue deux horizons, dont l'inférieur contient I. balticus Böhm: cette espèce-ci indique la transition du Campanien au Maestrichtien. Cette espèce commence son évolution dans le Campanien, en Allemagne, elle passe mème au Maestrichtien inférieur; en URSS elle est également connue dans le Maestrichtien moyen (KOCJUBINSZKIJ 1958). Dans les couches de marne et de calcaire qui gisent en concordance sur celle-là, c'est I. regularis d'Orb. qui est fréquent et dont l'extension verticale se borne au Maestrichtien. L'unique espèce de Gastéropode y récolté, c'est Campanile inauguratum (Stol.) qui, ayant une aire horizontale bien vaste, n'est connue que dans les formations maestrichtiens: Béloutchistane, Inde, Lybie, Madagascar, Perse. L'espèce Pachydiscus neubergicus Schloth. indique d'une manière sûre l'âge maestrichtien de ces formations. Dans le Bakony Méridional, on connaît deux horizons du groupe de marne et de calcaire à Inocérames; cependant, dans le Bakony septentrional (Magyarpolány, Németpolány) on distingue un troisième horizon, plus bas, est probablement *campanien supérieur*. A côté de l'espèce I. balticus Böhm, on y trouve également les espèces associées d'Inocérames, caractéristiques du Campanien: notamment: I. decipiens (Zittel) Aliev, I. capitosus Renngarten, I. cf. inconstans Zittel.

Sur le territoire du Bakony Septentrional, on a également démontré l'existence du *Maestrichtien supérieur*, sur la base d'analyses palynologiques et micropaléontologiques (GÓCZÁN, et SIDÓ).

L'aire paléogéographique des Inocérames est bien vaste: elle comprend l'Autriche, l'Allemagne, la Pologne, la France, la Roumanie, la Yougoslavie, la Grèce, la Tchécoslovaquie, l'Inde, le Madagascar, et l'Afrique du Nord. A ces territoires-là c'était dans le Maestrichtien que la transgression s'est complètement développée; alors il existait déjà une communication entre le territoire de la Hongrie et les territoires boréaux, ce qui se justifie par la présence des éléments identiques de la faune.

Tableau 1

âge		sédiment		faune		
étage	sous-étage	groupe		horizon	type faunique	
SÉNONIEN	Maestrichtien	calcaire et marne à Inocérames		Inoceramus regularis		
				Inoceramus baltica		
	Campanien supérieur	Marne à Gryphaea	calcaire à Coralliaires et Hippurites	Ostrea		
				Grervilleia		
				Aptyxella	A	
				Exogyra	B	
				Dentalium	CDE	
				Clavagella	F	
	Campanien inférieur	Marne argileuse à Coralliaires et Mollusques		Lamellibranches (Nucula corbula)	G H I J K	
				— Coralliaires	L	
				Gastéropodes— Pecten—Cardium	M N	Cerithium (Pirenella)
				Coralliaires	O	Glauconia
		Groupe houiller				
	Santonien supérieur					
Turonien		Argile bigarrée et conglomérat (bauxite)				

BIBLIOGRAPHIE

1. Astre, G.: Bull. Soc. hist. nat. de Toulouse **64,** 31—154, 1932. — 2. Astre, G.: Mém. Soc. Géol. Fr. N. S. T. **XXXIII,** 1—140, 1954. — 3. Sornay, J.: Bull. Soc. Géol. Fr. sér. **7,** 452—469, 1960. — 4. Barnabás, K.: Les relations géologiques et paléontologiques des couches du Crétacé supérieur de Sümeg. Dissertation, 1937. (Manuscrit). — 5. Bartha, F.: Földtani Közlöny **92,** 203—208, 1962a. — 6. Bartha, F.: Acta Géol. Sci. Hung. **7,** 3—4, 1963. — 7. Benkő-Czabalay, L.: Magyar Állami Földtani Intézet Évkönyve **49,** 559—561, 1961. — 8. Benkő-Czabalay, L.: Földtani Közlöny **91,** 421—425, 1962. — 9. Benkő-Czabalay, L., Magyar Állami Földtani Intézet Évi Jelentése az 1962. évről, 263—293, 1964a. — 10. Benkő-Czabalay, L.: Sitzungsber. Akad. Wiss. math. nat. Kl. I. Wien. **173,** 155—188, 1964b. — 11. Benkő-Czabalay, L.: Les faunes mollusques du Crétacé de la Montagne Bakony. Dissertation, 1964c. (Manuscrit). — 12. Benkő-Czabalay, L.: Magyar Állami Földtani Intézet Évi Jelentése az 1963. évről. (Sous press.) — 13. Benkő-Czabalay, L.—Kolosváry, G.: Acta biologica, N. ser. **X,** 117—123, 1964e. — 14. Benkő-Czabalay, L.: Die obersenone Hippuriten von Sümeg. (Manuscrit). 1964f. — 15. Böckh, J.: Földtani Intézet Évkönyve **III,** 1, 1874. — 16. Csillag-Teplánszky, E.: Les faunes mollusques du Crétacé supérieur à Hárskút de Sümeg. 1953. (Manuscrit). — 17. Darányi, F.: Bány. és Koh. Lapok **XII, (XC),** 4—5, 1957. — 18. Dubay, L.: Földtani Közlöny **86,** 251—264, 1956. — 19. Dubay, L.: Földtani Közlöny **92,** 257—264, 1962. — 20. Duboul, C.: Bull. Musée d'Hist. nat. Marseille, **4,** 45, 1947. — 21. Fabre-Taxy, S.: Ann. Pal. **37,** 83—122, 1951. — 22. Fabre-Taxy, S.: Ann. Pal. **XLV,** 55—72, 1959. — 23. Fülöp, J.: Magyar Állami Földtani Intézet Évkönyve **XLIX,** 3, 577—587, 1961. — 24. Géczy, B.: Geol. Hung. ser. Pal. **24,** 1—158, 1954. — 25. Góczán, F.: Magyar Állami Földtani Intézet Évkönyve **XLIX,** 3, 635—645, 1961. — 26. Góczán, F.: L'examen palinologique des relations sédiment-géologiques du Crétacé supérieur dans la Montagne Bakony .Dissertation, 1963 (Manuscrit). — 27. Hantken, M.: Magyar Állami Földtani Intézet Évkönyve **III**/5, 1—155, 1875. — 28. Hauer, F.: Jahrb. d. k. k. Geol. Reichsanst. Verhandl. **12,** 1861. — 29. Hiltermann, H.: Pal. Zeitschrift. Sonderheft **30,** 33—44, 1956. — 30. Hiltermann, H.: Geol. Congr. Rep. **18,** Sess. Great. Britain. 1948. — 31. Hojnos, R.: Földtani Intézet Évi Jelentése az 1939—40. évekről, **I,** 32—39, 1943. — 32. Jaskó, S.: A pápai Bakony földtani leírása. (Déscription géologique de Bakony à Pápa.) — Dissertation. Földtani szemle melléklete. 1935 (Manuscrit). — 33. Kocjubinszkij, S. P.: Akad. Nauk. Ukr. Sz. Sz. R. Lvovszkij Naukovo Prirodoznavcsij Muzej, Kiew — 1958. — 34. Kolosváry, G.: Magyar Állami Földtani Intézet Évkönyve **42,** 2, 67—123, 1954. — 35. Kopek, G.: Az ajkai barnakőszén medencerészlet bányaföldtani viszonyai. (Les relations géologiques du bassin houillier de Ajka.) Földtani Intézet Adattára. 1958. (Manuscrit.) — 36. Kopek, G.: Földtani Közlöny **91,** 413—420, 1961. — 37. Kutassy, E.: Földtani Intézet Évi Jelentése az 1933—35. évekről, 1591—1604, 1940. — 38. Kühn, O.: Sitzungsber. Akad. d. Wiss. Math.-nat. Kl. I. **156,** 181—200, 1947. — 39. Kühn, O.: Neues Jahrb. f. Min. u. Geol. Beil. **89,** 167—194, 1948. — 40. Id. Lóczy, L.: Les formations géologiques de l'environ du lac Balaton. A Balaton tudományos tanulmányozásának eredményei, **I**/1, Budapest, 1913. — 41. Lupu, M. et D.: Revue de Géol. et Géogr. **IV,** 234—256, 1960. — 42. Majzon, L.: Földtani Közlöny **86,** 44—56, 1956. — 43. Majzon, L.: Magyar Állami Földtani Intézet Évkönyve **XLIX,** 3, 593—644, 1961. — 44. Mitzopoulos, M.: Sitzungsber. Österr. Akad. Wiss. math.-nat. Kl. **163,** 79—93, 1959. — 45. Neubrandt, E.: Földtani Közlöny **79,** 119—125, 1949. — 46. ifj. Noszky, J.: Földtani Intézet Évi Jelentése az 1944. évről, 9—11, 1952. — 47. Ifj. Noszky, J.: Sümeg környékének földtani újrafelvétele. (Réambulation géologique de la région de Sümeg.) MÁFI Adattára, 1957 (Manuscrit). — 48. Oberhauser, R.: Jhb. Geol. Bundesanstalt, **106,** 1—88, 1963. — 49. Oppenheim, P.: Z. Deutsch. Geol. Ges. **44,** 697—819, 1892. — 50. Pejović, D.: Geol.Inst. «Jovan Zujović» Poszjebna izpadnja **8,** 1—140, 1957. — 51. Petković, K.—Pasić, M.: Ann. géol. Pénins. Balk. **17,** 140—146, 1949. — 52. Petkovic, K.: Glas. SAN. Oderj. prir. mat. nauka **XL,** 17—37, 1956. — 53. Plöchinger, B.—Bárdossy, Gy.—Oberhauser, R.: Jahrbuch Geol. Bundesanst. **104,** 359—414, 1961. — 54. Pokorny, G.: Sitzungsber. d. Akad. Wiss. math-nat. Kl. I. **168,** 945—978, 1959. — 55. Polšak, A.: Geoloski Vjesnik Inst. za Geol. Istraziv. u Zagrebu i. Hrvatsk. Geol. Drust. Svezak **15,** 435—454, broj 2 za godinu 1961., 1963. — 56. Polšak, A.: Bull. sci. Conseil Acad. RSF Yougoslavie **9,** 66—67, 1964. — 57. Rakusz, Gy.: Földtani Intézet Évi Jelentése az 1925—28. évekről, 127—129, 1935. — 58. Repelin, J.: Ann. Musée Hist. nat. **10,** 87, 1906. — 59. Rozlozsnik, P.: Földtani Intézet Évi Jelentése az 1920—23. évekről, 82—88, 1925. — 60. Rozlozsnik, P.: Führer in Ajkacsingervölgy. — Führer zu den Studienreisen der Pal. Ges. bei Gelegenheit des Palaeontologen-Tagen in Budapest, 1928. — 61. Rozlozsnik, P.: Földtani Intézet Évi Jelentése az 1933—35. évekről, 1179—1229, 1940. — 62. Schréter, Z.: Földtani Intézet Évi Jelentése az 1941—42. évekről. I. 161—196, 1941. — 63. Sidó, M.: L'évaluation géologique de Foraminifères sénoniennes

de Hongrie. Dissertation, 1962. (Manuscrit.) — 64. SIDÓ, M.: Földtani Közlöny **93,** 217—226, 1963. — 65. SLISKOVIČ, T.—PAPES, J.—RAIC, V.—LUBURUC, P.: Geol. Glasznik. **6,** 111—139, 1962. — 66. SZÖRÉNYI, E.: Geol. Hung. ser. Pal. 26, 1—186, 1955. — 67. TAUSCH, L.: Abh. d. k. k. Geol. Reichsanst. **XIII,** 1—32, 1886. — 68. TIEDT, L.: Sitzungsber. d. Österr. Ak. d. Wiss. math-nat. Kl. Abt. I. **167,** 483—517, 1958. — 69. VADÁSZ, E.: Magyarország földtana. Ak. Kiadó, Budapest, 1960. — 70. VESZELINOVICS, N.: Sbornik Geol. Inszt. «Jovan Zujović» knj. **10,** 73—82, 1958. — 72. VILLALTE, J.: Bull. Soc. d'Hist. nat. de Toulouse, **86,** 315—339, 1953. — 73. WICHER, C. A.: Pal. Zeitschrift **30,** 87—136, 1956. — 74. DECHASEAUX, C.: Comptes rendus du Congr. des Soc. Sav. de Paris et des Départ. Coll. sur le Crét. sup. franc. Dijon. Gauthier—Villard, Paris, 1959. — 75. TAXY, S., FABRE: Comptes rendus du Congr. des Sav. de Paris et des Départ. Coll. sur le Crét. sup. franc. Dijon, Gauthier-Villard, Paris, 1959. — 76. MARIE, P.: Comptes rendus du Congr. des Soc. Sav. de Paris et des départ. Coll. sur le Crétacé sup. franç. Dijon, Gauthier—Villard, Paris, 1959. — 77. SENESSE, P.: Comptes rendus du Congr. des Soc. Sav. de Paris et des départ. Coll. sur le Crétacé sup. franç. Dijon. Gauthier—Villard, Paris, 1959.

THE PALAEOGEOGRAPHICAL POSITION OF THE SENONIAN FAUNA OF HUNGARY

by

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Abstract

The results of the malacological investigations of the Hungarian Senonian are summarized and, the faunistic relations along with the palaeogeographical position of the fauna are outlined. The results are based on the malacological investigations of the Southern Bakony; howewer in the faunistic and stratigraphical interpretation and further in the determination of palaeogeographical relations, the fauna from all the Senonian formations of Hungary *(Northern Bakony, Bükk Mountains, Zala basin)* have been considered.

In the Southern Bakony, the sedimentary sequence of Upper Senonian settled up unconformable rests over the conglomerate and variegated clays, the latter belonging to the *Turonian.* The Lower Senonian is missing.

The *Upper Senonian* sedimentation began with the fresh-water coal deposits of the coal seam group. The fresh-water section is succeeded by those of reduced salt-content (oligo-mesohaline), and later by marine sections (BARTHA 1963).

Parallel with the first marine transgression a reef formation was deposited on the higher part of the tectonically preformed area: the Hippurites-corallic limestone-group.

The minor ingression and the regression of the sea and the oscillation of the salt content is further observable in the fauna of the successive layers in the lower beds of the coral-mollusc clay marl group (Glauconia facies), but the presence of solitary corals in the upper section confirms the stable state of salt content.

In the Gryphaea marl group six horizons, namely those of Clavagella, Dentalium, Exogyra, Aptyxiella, Gervilleia and Ostrea can be distinguished.

The heteropic facies of the hippurites-coralline limestone group is peen to rest over the upper section of the coal seam group and over the group of coralline-mollusc clay marl and Gryphaea marl respectively (Sümeg): elsewhere *(Ajka, Zala basin)* however it directly rest over the Gryphaea marl.

In the fauna of the Inoceramus limestone and marl group, the species of large horizontal extension confirm the establishment of open sea connection.

According to their geological evolution and fauna, the Senonian formations of Sümeg are closely related to the *Middle* and *Upper Gosau layers of Austria.* The number of southern elements is greater in the Hungarian fauna. The mollusc fauna is related to the Senonian fauna of *Austria, France, Yougoslavia, Greece, Roumania.* The southern elements come especially into the foreground especially in the Hippurites and Radiolites fauna of the Hippurites-corallic limestone group.

A large part of the faunistic elements coincide with the faunae of the Rudista limestones of *South France, North Spain (Pyrenees), Greece, Yougoslavia and Austria.* The fauna migrated from *South France* across the *Iberian peninsula, North Africa, Italy,* towards East, and across

the protruding arm of the Mediterranean sea partly from the direction of the *Zala basin* towards the *Bakony*, partly towards *Austria*. The sedimentation began in the *Upper Santonian* substage with deposition of coal and continued still in the *Lower Campanian* with coral-mollusc clay marl beds. The Gryphaea marl series was deposited during the *Upper Campanian*. The Hippurites-coral limestone-group as a heteropic facies of the former formations fills the entire *Campanian* around *Sümeg* (at Ajka and in the Zala basin, only its upper part is represented). The series is closed by the *Maastrichtian* formations of the Inoceramus limestone- and marl group.

ПАЛЕОГЕОГРАФИЧЕСКАЯ ОБСТАНОВКА СЕНОНСКОЙ ФАУНЫ В ВЕНГРИИ

Л. БЕНКЁ-ЦАБАЛАИ

Р е з ю м е

Автором подводятся итоги изучения сенонских моллюсков Венгрии, дается схематическая характеристика фаунистических связей и палеогеографического распространения фауны. Результаты основываются на малакологическом изучении сенонских отложений южной части гор Баконь; однако, при фаунистической и стратиграфической оценках, а также при определении палеогеографических соотношений были учтены также сенонские отложения других районов Венгрии (северный участок гор Баконь, горы Бюкк, Залайский бассейн).

В южной части гор Баконь верхнесенонская осадочная толща несогласно налегает на толщу конгломератов и пестрых глин, отнесенных к туронскому ярусу. Нижний сенон отсутствует.

Верхнесенонская седиментация началась отложением пресноводных угольных пластов угленосной толщи. Пресноводному этапу последовал сначала солоноватоводный (олиго-мезогалинный), а затем наступили морские этапы (Барта, 1963).

Параллельно первой морской ингрессии в более приподнятой части тектонически преформированного района отложились рифовые осадки — пачка известняков с гиппуритами и кораллами. Небольшие ингрессия и регрессия моря, отражаемые колебанием солености, наблюдаются также на фауне базальных слоев (глаукониевая биофация) пачки глинистых мергелей с кораллами и моллюсками, но появление единичных кораллов в верхнем участке разреза свидетельствует о стабилизации солености.

В пачке грифеевых мергелей можно выделить шесть горизонтов: горизонт с **Clavagella**, горизонт с **Dentalium**, горизонт с **Exogyra**, горизонт с **Aptyxiella**, горизонт с **Gervilleia** и горизонт с **Ostrea**. Пачка известняков с гиппуритами и кораллами представляет собой гетеропическую фацию верхней части угленосной толщи — пачек глинистых мергелей с кораллами и моллюсками и грифеевых мергелей (Шюмег). В других районах (Айка, Залайский бассейн) она налегает непосредственно на грифеевые мергели. В фауне пачки иноцерамовых известняков и мергелей присутствие форм широкого горизонтального распространения доказывает осуществление связы с открытым морем.

По своему геологическому строению и фауне сенонские отложения Шюмега совсем близки к средне- и верхнегозауским отложениям Австрии. В венгерской фауне количество южных элементов больше. Моллюсковая фауна обнаруживает непосредственные связи с сенонскими фаунами Австрии, Франции, Югославии, Греции и Румынии. Южные элементы больше всего преобладают в гиппуритовой и радиолитовой фауне пачки известняков с гиппуритамии и кораллами, так как большинство фаунистических элементов соответствует главным образом формам, известным из рудистовых известняков Южной Франции, Северной Испании (Пиренеи), Греции, Югославии и Австрии. Миграция фауны поступала из Южной Франции через Иберийский полуостров, Северную Африку и Италию дальше на восток, а на территории северного ответвления Средиземноморского бассейна — со стороны Залайского бассейна в направлении гор Баконь и в направлении Австрии.

В верхнесантонское время осадконакопление началось образованием угля и продолжалось отложением глинистых мергелей с кораллами и моллюсками в нижнекампанское время. Серия грифеевых мергелей отложилась в верхнем кампане. Пачка известняков с гиппуритами и кораллами, как гетеропическая фация вышеприведенных образований, занимает весь стратиграфический интервал кампанского яруса в районе г. Шюмег (в г. Айка и в Залайском бассейне представлена только верхняя часть ее). Толща завершается маастрихтскими образованиями пачки иноцерамовых известняков и мергелей.

STRATIGRAPHISCHE PROBLEME DES EOZÄNS IM TRANSDANUBISCHEN MITTELGEBIRGE UNGARNS

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UNTERNEHMEN FÜR BAUXITPROSPEKTION, BALATONALMÁDI

Die eozäne Schichtenfolge Transdanubiens ist nicht (wie bisher angenommen) kontinuierlich, sondern durch drei Aushebungsphasen und nachfolgende, weiter fortschreitende Transgressionen gegliedert. Dementsprechend sind auch die Braunkohlenbildungen unterschiedlichen Alters.

Die Verfasser benutzten von der Bearbeitung vieler Tiefbohrungen ausgehend zur stratigraphischen Feingliederung vor allem die Großforaminiferen. In 15 charakteristischen Profilen ließen sich (vom unteren Yprésien bis zum oberen Priabonien einschließlich) insgesamt XVI Horizonte unterscheiden. Sie werden in erdgeschichtlicher Reihenfolge besprochen, u. zw. mit besonderer Berücksichtigung jener drei Leithorizonte (N. laevigatus, N. perforatus und N. fabianii, N. wemmelensis), die eine gute Möglichkeit zur Korrelierung mit den Eozänbildungen anderer Länder bieten.

Einleitung

In der stratigraphischen Beurteilung der einzelnen Bildungen bzw. Schichtenreihen des transdanubischen Eozäns gehen die Meinungen auseinander. Als Beispiel seien die sog. »Fornaer Schichten« erwähnt, denen während der letzten siebzig Jahre vom Paleozän bis zum Obereozän alle möglichen Alter zugeschrieben wurden.

Diese Unsicherheit hat viele Gründe, vor allem erklärt sie sich aber aus jener Auffassung, daß man es im Transdanubischen Mittelgebirge mit einer kontinuierlichen oberpaleozänen-eozänen Sedimentation zu tun habe.

Im Gegensatz zu dieser Ansicht ergab sich aus neueren, in den letzten Jahren durchgeführten Untersuchungen (KOPEK 1964, KOPEK – KECSKEMÉTI 1964 a, b, 1965), daß *die eozäne Schichtenreihe Transdanubiens lückenhaft, durch drei bedeutende Aushebungsphasen und darauf folgende Transgressionen gegliedert ist.*

Als gemeinsame Züge dieser Meeresüberflutungen können hervorgehoben werden

1. daß sie immer eine größere Ausdehnung aufweisen,
2. daß sie in gewissen Fällen gesondert, in verschiedenen Ausbildungszonen auftreten,
3. daß sich an ihrer Basis paralische, größtenteils abbauwürdige Braunkohlenbildungen finden.

Diese Tatsachen waren früher nicht erkannt, weshalb alle Braunkohlenkomplexe einheitlich auf die Basis der ganzen Schichtenfolge »gesenkt« wurden. Daraus entstand eine Verwirrung in der Beurteilung der einzelnen stratigraphischen Horizonte. Der *Alveolina cf. oblonga* und *Alveolina cf. rütimeyeri* führende Braunkohlenkomplex, dessen Hangendes *Nummulites subplanulatus* enthielt, wurde als gleichaltrig mit dem anderen aufgefaßt und behandelt, der von einer oberlutetischen Fauna begleitet ist *(Nummulites perforatus, N. millecaput, N. brogniarti, Tubulostium spirulaeum).*

Nach dem Tode von HANTKEN und ROZLOZSNIK wurden die Großforaminiferenstudien in Ungarn vernachlässigt. Es wurde versucht, eine stratigraphische Gliederung anhand der Mollusken durchzuführen, doch sind diese am meisten faziesbedingt. Wenn man in Betracht zieht, daß das Eozän-Meer Transdanubiens als ein oszillativ-epikontinentales Flachmeer, manchenorts sogar als ein Archipel mit rapidem vertikalem und horizontalem Fazieswechsel (und entsprechenden Mollusken-Vergesellschaftungen) gedeutet werden muß, wird man die aus dieser Methode entstandenen Schwierigkeiten leicht verstehen, zumal einige sogenannte »Leitfossilien« des Untereozäns (z. B. *Turritella tokodensis*) auch in höheren Horizonten des Mitteleozäns zum Vorschein kamen.

Dennoch sind die Verfasser fest davon überzeugt, daß eine Neubearbeitung der gründlich gesammelten Molluskenfauna jener Fundorte, deren stratigraphische Lage in unserer Großforaminiferen-Stufenreihe einwandfrei bestimmt ist, die Auswahl der wirklich leitenden Molluskenarten ermöglichen wird.

Die vorliegende Arbeit stützt sich außer auf zahlreiche Aufschlüsse (deren Liegendes bzw. Hangendes sich leider oft nicht feststellen läßt) vor allem auf das Tiefbohrungsnetz des Braunkohlentrusts und des Unternehmens für Bauxitprospektion, welches das ganze Gebiet des Transdanubischen Mittelgebirges umfaßt.*

Der Dimorphismus der Großforaminiferen, insbesondere die Tatsache, daß die Großformen die litorale Region, die Kleinformen dagegen das Innere des Beckens bevorzugten, stellt eine vorzügliche Möglichkeit zur Korrelierung beider Faziesgebiete dar.

Natürlich gibt es unter den Großforaminiferen außer den guten Leitformen (wie *Nummulites laevigatus, N. perforatus, N. fabianii)* auch Arten, die eine größere vertikale Verbreitung haben (z. B. *N. striatus, N. variolarius, N. incrassatus)*, doch leisteten diese — mit der nötigen Vorsicht verwendet — auch bei der Bestimmung der unteren Grenze der Schichtenfolgen Transdanubiens gute Dienste.

In der ungarischen Fachliteratur gibt es Beispiele für das vereinzelte Vorkommen gewisser Arten in unwahrscheinlich tiefen bzw. hohen Horizon-

* Für die kollegiale Zusammenarbeit und Unterstützung durch die genannten Institutionen sprechen die Verfasser ihren aufrichtigen Dank aus.

ten. In solchen Fällen dürfte entweder die Bestimmung oder die Einstufung der Fundschichten irrig gewesen sein.

Bei der Parallelisierung des transdanubischen Eozäns wurden *drei Leithorizonte ersten Ranges* angenommen, deren Leitarten in ganz Europa als gut fixierte Leitformen gelten und in Ungarn häufig vorkommen. Es sind dies *Nummulites laevigatus* (unteres Lutetien), *Nummulites perforatus* (oberes Lutetien) und *Nummulites fabianii* (unteres Priabonien).

Horizonte zweiten Ranges sind diejenigen, die im betrachteten Gebiet Ungarns in bezug auf die vorigen Leithorizonte konsequent in derselben Position zu finden sind und eine breite horizontale (geographische) Verbreitung besitzen. Sie sind z. T. durch kennzeichnende Arten (z. B. *Nummulites millecaput*) oder durch leicht erkennbare und weit zu verfolgende lithologische Merkmale (z. B. durch hohen Glaukonitgehalt) charakterisiert. Diese Horizonte sind für das ganze Transdanubische Mittelgebirge gültig. Ihre Abwesenheit in einem Profil deutet ausnahmslos Aushebungs bzw. Abtragungserscheinungen an.

Die Braunkohlenkomplexe bilden je einen sedimentären »Kleinzyklus« (Mikrozyklothem), der in einem so stark oszillativen Gebiet die Dauer einer Stufe nicht überschreitet. Die Schwankungen des Bodens sind auch innerhalb der Braunkohlenbildung selbst erfaßbar: im Terrestrikum konnten Süßwasser-, im limnischen Teil brackische und in der Brackwasser-Etappe echt marine Zwischenlagerungen belegt werden. Es ist von größter Wichtigkeit, daß *die Meerwasser-Einlagerungen schon die charakteristischen Großforaminiferen des marinen Hangenden enthalten.* Die abgegrenzten Horizonte sind mit römischen Ziffern (I—XVI), die angeführten typischen Profile im großen und ganzen von SW nach NO fortschreitend mit gewöhnlichen arabischen Ziffern (1—15) versehen.

Paleozän

Paleozäne Ablagerungen konnten im Transdanubischen Mittelgebirge faunistisch *nicht* nachgewiesen werden. Pollenanalytische Angaben scheinen das paleozäne Alter gewisser Sedimente zu verwahrscheinlichen, die Ergebnisse sind aber noch nicht überzeugend.

Untereozän (Yprésien = Cuisien)

I. *Alveolina oblonga-Horizont*

Diese Ablagerungen sind meist aus Tiefbohrungen (Dv-2), seltener aus Aufschlüssen (bei Sümeg und Urkút) bekannt. Sie bestehen aus terrestrischen, brackischen und marinen Bildungen. Auf Grund der Großforaminiferenfauna lassen sich ein tieferer und ein höherer Unterhorizont unterscheiden.

Der tiefere Unterhorizont enthielt unteryprésische Formen: *Alveolina cf. oblonga, Alveolina cf. rütimeyeri* (1-I, KOPEK—KECSKEMÉTI 1964 a), *Nummulites burdigalensis, N. partschi* (4-I, DUDICH jr.—HŐRISZT 1964). Sie sind für den unteren Teil des Cuisiens charakteristisch (HOTTINGER—SCHAUB 1964). Die für den oberen Unterhorizont charakteristische Art ist dem *Nummulites laevigatus* ähnlich, zeigt aber wesentlich abweichende Merkmale (1-I, 3-I). Die Untersuchungen sind noch im Gange, vermutlich handelt es sich aber um eine neue, stratigraphisch ältere Art der »Laevigatus«-Gruppe (N.? »vetolaevigatus« n. sp.), die vielleicht mit dem *»praelaevigatus«* (HOTTINGER—SCHAUB 1964) identifiziert werden kann.

Die *Urkúter Schichten* konnten mangels einer Großforaminiferenfauna bloß ihrer Lage nach eingestuft werden. Es besteht nämlich eine Diskordanz zwischen ihnen und dem darüber lagernden *Nummulites laevigatus* enthaltenden Kalkstein (KOPEK—KECSKEMÉTI 1964 a). Das ist *die erste eozäne Aushebungsphase.*

Der Alveolinenkalk an der Basis des Eozäns von *Fehérvárcsurgó* (im sog. »Graben« von *Mór*) ist nur vorläufig hierher gestellt, weil noch keine entscheidenden Angaben zur Verfügung stehen.

Mitteleozän (Lutetien)

II. *Unterlutetischer Braunkohlenkomplex*

Die Braunkohlenflöze sind im unteren Teile in Süßwasser-, im oberen Teile schon in Brackwasser-Fazies entwickelt. In der Gegend von *Dudar* (6-II) und *Balinka* (7-II) sind sie abbauwürdig, bei *Halimba* und *Ajka* dagegen nicht (3-II). Im unmittelbaren Liegenden finden sich überall bunte Tone. Das Alter des Komplexes ist durch *Nummulites laevigatus* (3-III) bzw. *N. sismondai* und *N. deshayesi* (6-III) im Hangenden eindeutig bestimmt. (KOPEK—KECSKEMÉTI 1964 a, 1964 b).

III. *Nummulites laevigatus-Horizont*

Mit diesem Horizont beginnt die erste mitteleozäne *(die zweite eozäne) Transgressionsphase.*

Im SW (bei Szőc, Ajka, Halimba, Devecser-Szőrtetőpuszta) ist dieser Horizont durch *Nummulites laevigatus* charakterisiert, begleitet von *N. baconicus Hantk. in. coll.* (2-III, 3-III) und *N. sismondai, N. deshayesi,* im oberen Teil noch durch *Alveolinen* (2-III, 3-III, 4-III). Seltener kommen auch *Discocycliniden* und *Assilinen* vor.

Im NO bei Dudar sind aus dem mergeligen Hangenden des Braunkohlenkomplexes nur *N. sismondai* und *N. deshayesi* bekannt (6-III). Die Behauptung

SCHAUBS (1964), daß diese Arten einen etwas höheren Horizont bezeichnen, halten Verfasser für unwahrscheinlich, weil die beiden Arten im südwestlichen Bakony-Gebirge mit *N. laevigatus* vergesellschaftet sind. Es liegen (von den Verfassern bis jetzt noch nicht kontrollierte) Angaben über das Vorkommen von *N. laevigatus* am Ostrande des Bakony-Gebirges bei Iszkaszentgyörgy (8-III) vor.

IV. *Horizont der intralutetischen Denudation*

Eine *zweite* allgemeine, mit einer Alveolinen-Fazies eingeleitete *Aushebung* und nachfolgende Abtragung hatte die partielle Abtragung der *N. laevigatus*-Schichten zur Folge. Diese Abtragungserscheinungen im Transdanubischen Mittelgebirge, die in den verschiedenen Teilgebieten von unterschiedlicher Dauer waren, wurden als »*intralutetische Denudation*« eingeführt (KOPEK—KECSKEMÉTI 1964 a, 1965). Am längsten dauerte sie im westlichen Gebiet (im Bakony und im westlichen Vértes-Gebirge), wo auch die Horizonte V—VIII fehlen.

Horizonte V-VIII — der zweite Kleinzyklus

Die *dritte Transgressionsphase* nahm ihren Anfang mit dem V. Horizont (Terrestrikum), u. zw. zwischen dem Becken von Tatabánya und dem Budaer-Gebirge.

Damit sind wir zum schwersten Problem des vorliegenden Aufsatzes gelangt, das eine etwas eingehendere Darstellung (und weitere Detailuntersuchungen) erfordert.

In dem Becken von Tatabánya und Dorog und auch im Budaer-Gebirge (11-15—V-VIII) findet man an der Basis der eozänen Schichtenfolge einen Komplex, der aus terrestrischen, braunkohlenführenden limnischen bzw. brackischen und endlich marinen Ablagerungen besteht. Die letzteren enthalten *Nummulites subplanulatus* (11-14—VII-IX) und *N. kovácsiensis* (15—VIII-IX). Die nichtmarinen unteren Schichten hielt man für Paleozän, andere Forscher dagegen halten sie eben auf Grund des *N. subplanulatus* für Untereozän. Der »Locus typicus« dieser Art ist der Reimann-Schacht von Csolnok bei Esztergom im Komitat Komárom. Es wurde angenommen, diese Art sei für die yprésische Stufe charakteristisch.

Diese Schichtenfolge stellt ein vorzügliches Beispiel für einen sedimentären Kleinzyklus dar.

Neuere Angaben (MUNTYÁN 1964) haben einwandfrei bewiesen, daß *Nummulites subplanulatus* im Doroger Becken auch schon innerhalb des Braunkohlenkomplexes, in marinen Einlagerungen, ja sogar in gesteinsbildendem Maße vorkommt. Demnach kann die Möglichkeit des paleozänen Alters

endgültig ausgeschaltet werden und man muß nun zwischen Unter- und Mitteleozän entscheiden.

In den Becken von Tatabánya und Dorog (11-14) kommt nur *N. subplanulatus* vor, im Budaer-Gebirge im Gegensatz hierzu nur *N. kovácsiensis* (15). Die umstrittenen Schichten gehen in beiden Gebieten nach oben in die oberlutetischen *Nummulites perforatus* führenden Schichten über: es gibt Mergel, die *N. subplanulatus* und *N. perforatus* nebeneinander enthalten (HANTKEN 1871, ROZLOZSNIK 1922, SZŐTS 1956), und andere, in denen *N. kovácsiensis* mit *N. perforatus* gemeinsam gefunden wurde (im oberen Teil des Profils der Zwieržina-Grube nach HANTKEN 1885, ROZLOZSNIK 1924, SZŐTS 1956).

ROZLOZSNIK stellte die *N. kovácsiensis*-Schichten *über* die *N. sub planulatus* führende Schichtenreihe in den unteren Teil des *N. perforatus*-Horizontes. Die Verfasser haben dieselbe Übergangsserie in der Tiefbohrung Solymár-72 gefunden, in der *N. kovácsiensis* von *N. perforatus*, *N. brongniarti*, *N. discorbinus* und *N. millecaput* begleitet ist.

Aus diesen Tatsachen ergeben sich folgende Schlüsse:

1. *Nummulites subplanulatus* und *N. kovácsiensis* sind *keine Leitformen* des Yprésiens, sie kommen auch an der Basis das oberen Lutetiens vor. Selbst HANTKEN bezweifelte das yprésische Alter der Art. Auf einer Etikette unter einem *N. subplanulatus*-Exemplar bezeichnete er das Alter als »Mitteleozän«.

2. Die oberen Teile der *N. subplanulatus* und der *N. kovácsiensis* führenden Schichtengruppe — *N. perforatus* erscheint in beiden — sind miteinander gleichaltrig.

3. Das gemeinsame Vorkommen von *N. subplanulatus* und *N. kovácsiensis* im Becken von Nagykovácsi (HANTKEN 1865, HOFFMANN 1871, ROZLOZSNIK 1924, SZŐTS 1956) bestätigt die Gleichaltrigkeit der *unteren* Teile der beiden Schichtengruppen.

Während für die lutetische Position beider Arten entscheidende Beweise ins Treffen geführt werden konnten, gibt es bloß einige unsichere Begleitarten, die als für Untereozän sprechend interpretiert werden konnten. Es handelt sich um die folgenden:

1. *Nummulites atacicus*. Die Art ist im südlichen Mittelmeer-Gebiet nach SCHAUB (1951) Untereozän, im Krim-Kaukasus-Gebiet (Armenien—Grusien) nach NEMKOW—BARCHATOWA (1961), KATSCHARAWA—KATSCHARAWA (1964) und GABRIELJAN (1964) Mitteleozän, in der polnischen Tatra kommt sie selbst in den Übergangsschichten vom Mittel- zum Obereozän vor (BIEDA 1963).

VITÁLIS (1939) bezeichnete eben im Hinblick auf das massenhafte Vorkommen dieser Art im Gebiet von Tatabánya einen Mergel geradeswegs als »*N. atacicus*-Mergel«. Alle anderen Forscher haben dagegen diese Form gar

nicht erwähnt. Es muß angenommen werden, daß es sich um eine Verwechslung mit *N. subplanulatus* handelt, der nämlich in den fraglichen Schichten tatsächlich gesteinsbildend ist.

2. *Nummulites planulatus* (allgemein für Untereozän gehalten) ist aus einem einzigen Fundort erwähnt (14-VIII., MUNTYÁN 1964) u. zw. unter Bezugnahme auf die durch KECSKEMÉTI erfolgte, mit Fragezeichen ausgestattete Bestimmung eines einzigen Exemplares.

3. *Nummulites globulus* scheint ziemlich lang gelebt zu haben. Die Art kommt sehr oft in Gesellschaft von *N. atacicus*, *N. partschi*, *N. rotularius* vor, in der Schweiz im Untereozän (SCHAUB 1951), im Krim-Kaukasus-Gebiet nach den soeben zitierten sowjetischen Forschern auch im Mitteleozän. J. BOUSSAC (1911) erwähnt sie *nur* aus dem Mitteleozän! Diese Art ist aus einer einzigen Fundstelle im Doroger Becken begleitet von *N. subplanulatus* bekannt (14-VIII MUNTYÁN 1964).

Die für eine tiefere Lage sprechenden Argumente sind also mehr als unsicher. Das vielfach belegte Vorkommen von *Assilina exponens* und *Nummulites perforatus* beweist dagegen zweifellos das Lutetien. Die Auffassung der Verfasser des vorliegenden Aufsatzes, daß nämlich die *N. subplanulatus* und *N. kovácsiensis*-Schichten jünger sind als der (III) *N. laevigatus*-Horizont des Bakony-Gebirges, stützt sich einerseits auf die vollkommene Abwesenheit von *N. laevigatus*, andererseits auf das regelmäßige Vorkommen von *N. variolarius mut.* (14-VIII, ROZLOZSNIK 1922), *N. striatus* (HANTKEN 1865, 15-VIII) und *Tubulostium spirulaeum* (11-VIII, TAEGER 1909). In dem von den Verfassern gründlich bearbeiteten Profil der Tiefbohrung Solymár-72 bildet *N. striatus* einen selbständigen Horizont (15-VII) *unter* (!) den *N. kovácsiensis* enthaltenden Schichten und kommt auch im Brackwasserton des Braunkohlenkomplexes vor.

IX. *Oszillativer »Übergangshorizont«*

Die so bezeichnete Schichtenfolge ist in drei Faziestypen ausgebildet, deren gemeinsamen Zug der allmähliche Übergang nach oben in die *Nummulites perforatus*-Schichten bildet.

A) Die Ausbildung des Gebietes von Sümeg bis Pénzesgyőr (1-4—IX) kann den Namen *»Assilina-spira-Schichten«* erhalten. An der Basis (über der intralutetischen Denudationsoberfläche) kommen *Miliolinen*, *Alveolina elongata* und eine andere, noch nicht bestimmte, 2—4 cm lange *Alveolina*-Art vor. Die Fauna enthielt außerdem *Assilina spira*, *A. praespira*, *Nummulites aturicus*; seltener sind *N. baconicus Hantk. in. coll.*, eine kleinere und dickere Form von *N. millecaput* und *Tubulostium spirulaeum*. Gegen die obere Grenze der Schichtengruppe hin erscheinen schon *N. perforatus* und *Assilina exponens*.

B) Die Ausbildung von Pénzesgyőr bis Oroszlány (5-10—IX). Die marinen Ablagerungen der soeben besprochenen Gegend gehen nach NO in brackische Sedimente über. Zwischen Magyarpolány, Pénzesgyőr und Olaszfalu (4-5) finden sich nicht abbauwürdige Braunkohlenlinsen mit *Assilina spira* und *Nummulites puschi* enthaltenden marinen Einlagerungen. Im Gebiet von Dudar, Balinka, Mór in den Tagebau-Aufschlüssen von Pusztavám und am Ostrand der Region von Oroszlány (6, 7, 10—IX) sind zwei abbauwürdige Flöze bekannt. Im unteren Teil befinden sich Süßwasser-, im Hangenden brackische Ablagerungen mit »*Fornaer Fauna*«. In der Nähe der Flöze sind *Brachyodontes corrugatus* und *Anomia gregaria* oft gesteinsbildend. Darüber lagern *N. perforatus* und *N. brongniarti* führende Schichten.

Die zweifellos bestehende Kontinuität der Ablagerung sowie das Vorkommen von *N. striatus* zwischen dem oberen Flöz und dem sog. Begleitflöz beweisen das oberlutetische Alter des Braunkohlenkomplexes (KOPEK—KECSKEMÉTI 1964 a, b, 1965).

Dieselbe Schichtenfolge enthielt bei Iszkaszentgyörgy (8-IX) und bei Csákberény (IX-9) nicht abbauwürdige Braunkohlenlinsen, die ebenfalls von *N. striatus* begleitet sind.

C) Für die Ausbildung des zwischen Oroszlány und Budapest liegenden Gebietes (11-15—IX) sind wiederholt vorkommende brackische Zwischenlagerungen in einer marinen Schichtenfolge kennzeichnend. Bei Nagyegyháza lassen sich Spuren lokaler Diskordanz bzw. Abtragung (12-IX), bei Csolnok (14-IX) Braunkohlenlinsen feststellen. Die Fauna enthielt *N. subplanulatus*, *N. kovácsiensis*, *N. perforatus*, *N. striatus*, *N. millecaput*, *N. brongniarti*, *N. discorbinus*, außerdem die für jede eozäne Braunkohlenbildung gemeinsamen, also stratigraphisch wertlosen Arten *Brachyodontes corrugatus* und *Anomia gregaria*.

Aus den vergleichenden Profilen geht deutlich hervor, daß die zweite (intralutetische) Denudation je nach der Gegend unterschiedlich lange dauerte: im nordöstlichen Gebiet begann die Senkung, Braunkohlenbildung und die Transgression wesentlich früher als im SW; *die Braunkohlenbildungen sind verschiedenen Alters und die dritte eozäne Transgression erfolgte in mehreren Etappen.*

X. *Nummulites perforatus-Horizonte*

Diese Schichten, in denen *N. perforatus* immer, meistens in gesteinsbildender Menge vorkommt, stellen einen für die außer-ungarländische Korrelierung sehr wichtigen Leithorizont dar, obzwar die Begleitfauna in den verschiedenen Profilen erhebliche Unterschiede aufweist.

Im *N. perforatus*-Horizont schritt die mit den *N. subplanulatus*—*N. kovácsiensis*-Schichten (VIII) begonnene und mit den Übergangsschichten

(IX) weiter ausgedehnte Transgression fort. Die Schichtengruppe besitzt trotzdem einen stark schwankenden Charakter mit lokalen Erosionsspuren (5-X) mit Kreuz- und Schrägschichtung (4-X), Tuffitbildung (7-8—X) ja selbst mit braunkohlenführenden brackischen Zwischenlagern (11-X). Im Bakony und im westlichen Vértes-Gebirge ist sie lithologisch und faunistisch sehr einheitlich und von bedeutender Mächtigkeit (1-10—X-XI). Zwischen Tatabánya und Budapest (11-15) läßt sie sich in zwei Teile auflösen: der untere Teil (X) ist durch *N. perforatus* und *N. brongniarti*, der obere (XI) durch *N. striatus* charakterisiert.

Im ganzen Transdanubischen Mittelgebirge sind die *N. perforatus*-Schichten von den *N. millecaput* führenden Bildungen bedeckt.

A) Bakony- und westliches Vértes-Gebirge

Im Gebiet von Sümeg—Magyarpolány (1-4—X-XI) sind neben *N. perforatus* die Arten *N. aturicus*, *Assilina exponens*, *N. striatus* charakteristisch. Im unteren Teil kommen auch *Assilina spira*, in der oberen Hälfte *N. millecaput* vor. Die Zahl von *N. striatus* wird nach oben hin immer größer, was die stratigraphische Gleichwertigkeit mit den *N. striatus*-Schichten des Beckens von Tatabánya betont.

In der Umgebung von Pénzesgyőr und Bakonynána (5—X-XI) spielt neben *N. perforatus* auch *N. puschi* eine wichtige Rolle. Zwischen Dudar und Pusztavám nimmt die Bedeutung von *N. brongniarti*, *N. discorbinus*, *N. striatus*, *Alveolina fusiformis* und *Alveolina fragilis* zu, *N. striatus* wird auch hier im oberen Teil immer häufiger. In dieser Gegend fällt das Fehlen der *Assilinen* auf. Im westlichen Vértes (Umgebung von Várgesztes) ist *Assilina exponens* wieder gesteinsbildend.

B) Tatabánya-Budaer-Gebirge

In diesem Gebiet sind die Arten *Nummulites perforatus*, *N. brongniarti* *N. striatus*, *Alveolina fusiformis*, *Alveolina fragilis*, *Assilina exponens* charakteristisch im Budaer Gebirge auch *N. discorbinus* (15-X). Die Schichten sind lithologisch und faunistisch einheitlich, weichen aber von dem weiter oben besprochenen Gebiet ab. Bei Tatabánya und Nagyegyháza finden sich in den oberen Schichten bereits *N. variolarius*, *N. garnieri*, *N. millecaput*, *N. incrassatus*. *N. millecaput* kommt auch in anderen Profilen vor.

XI. Der *Nummulites-striatus-Horizont*

Als selbständige Einheit läßt sich am besten zwischen Tatabánya und Budapest abgrenzen. Die lithologischen Profile zeigen viele Schwankungserscheinungen (Wechsellagerung brackischer und mariner Sedimente, Braunkohlenlinsen, kalkige Sandsteine). Die wichtigste Art ist *N. striatus*, an zweiter

Stelle steht *N. perforatus*. *Discocyclinen* und *N. millecaput* werden allmählich häufiger. Sporadisch treten *N. variolarius*, *N. garnieri*, *N. incrassatus*, *Tubulostium spirulaeum* und immer mehr auch *Operculinen* hinzu.

XII. *Nummulites-millecaput-Horizont*

Dieser sehr wichtige Horizont ist im ganzen Transdanubischen Mittelgebirge bekannt, ausgenommen das Budaer Gebirge, wo er — infolge der *dritten innereozänen Denudation*, die durch die *präpyrenäischen Bewegungen* verursacht wurde — ganz fehlt (DUDICH jr., MÉSZÁROS 1964). Er liegt über *N. perforatus* bzw. *N. striatus* führenden Schichten und ist von glaukonitischen Mergeln des folgenden Horizontes bedeckt. In der älteren Literatur sind sie als *N. tchihatcheffi*-Schichten bekannt.*

Im unteren Teil finden sich noch *N. perforatus*, *N. striatus*, *N. brongniarti*, *Assilina exponens* (8-11—XII), charakteristisch sind aber die in gesteinsbildender Häufigkeit vorhandenen *N. millecaput* und *Discocycliniden*. Bei Tatabánya (11-XII) kommen neben *N. perforatus* auch *N. gisehensis* und als lokale Art *N. böckhi* vor. Quantitativ sind die ins Obereozän hinaufreichenden Formen *N. incrassatus*, *N. chavannesi*, *N. variolarius* von größerer Bedeutung.

Aus den anderen Tiergruppen sollen zuerst die formenreichen *Echinoiden* erwähnt werden. *Conoclypus conoideus* ist im Transdanubischen Mittelgebirge sehr verbreitet. Im Profil von Iszkaszentgyörgy wurden (durch Frau SZÖRÉNYI, deren diesbezügliche Arbeit bald veröffentlicht werden soll) in den *N. millecaput*-Schichten folgende *Echinoiden* bestimmt: *Porocidaris schmidelii*, *Eoscutum calvimontanum*, *Conoclypus conoideus*, *Ditremaster nux*, *Linthia scarabaeus*, *Lutetiaster heberti*, *Schizaster ajkaensis*, *S. globulus*, *S. latus*, *S. lucidus*, *S. princeps*, *Macropneustes brissoides*, *Brissoides multituberculatus*, *B. veronensis*.

Charakteristisch ist auch *Terebratulina tenuicostata* bzw. die juvenile Form dieser Art, die auch in Tiefbohrungen vorkommt. *Tubulostium spirulaeum* ist in allen Profilen anwesend. *Rote Algen* (»*Lithothamnien*« s. l.) weisen manchenorts eine größere Anreicherung auf.

Zwischen den Forschern des südwestlichen und des nordöstlichen Ausbildungsgebietes des europäischen Eozäns bestehen in der Beurteilung des stratigraphischen Wertes von *N. millecaput* wesentliche Meinungsverschiedenheiten. Nach HOTTINGER und SCHAUB (1960) sowie nach SCHAUB (1964) stirbt *N. millecaput* beim Auftreten von *N. perforatus* und *N. brongniarti* aus. BIEDA (1963) und NEMKOW (1964) sind demgegenüber der Ansicht, daß *N. millecaput* bis in den unteren Teil des Obereozäns hinaufreicht.

* v. HANTKEN 1871. »*N. tchihatcheffi*« sollte die makrosphärische Generation von *N. millecaput* (in der alten Nomenklatur *N. helveticus*) bezeichnen. Das ist aber falsch, weil *N. tchihatcheffi* die Form A der *N. distans* ist, die aber in Ungarn noch nicht zum Vorschein kam.

In Ungarn kommt zwar *N. millecaput* bereits in den *N. perforatus*-Schichten vor, tritt jedoch massenhaft und horizontbildend erst über diesen auf (in Gesellschaft von typischen oberlutetischen Arten wie *N. perforatus*, *N. brongniarti*, *Assilina exponens*), und gelegentlich kann er auch im glaukonitischen Mergel angetroffen werden. Aus diesem Grunde haben die Verfasser gegen die Einführung des »Biarritziens« in die Eozän-Stratigraphie Ungarns Stellung genommen. In den *N. fabianii*-führenden Schichten kommt *N. millecaput* nicht mehr vor.

XIII. *Discocycliniden-führender glaukonitischer Mergel-Horizont*

Im Gegensatz zu den bisher beschriebenen muß dieser Horizont vorwiegend lithologisch charakterisiert werden. Er ist im ganzen Transdanubischen Mittelgebirge (wieder mit Ausnahme des Budaer Gebirges) allgemein verbreitet, und besteht größtenteils aus stark glaukonitischen, fossilarmen Mergeln, Kalkmergeln und Kalken mit tuffitischem Material. Die relativ häufigeren Faunaelemente sind *Discocycliniden*, *Tubulostium spirulaeum* und (meistens im Westen) *Dekapoden*. *N. millecaput*-Exemplare sind in allen Profilen anzutreffen; auch *N. perforatus* (11-12) und *Assilina exponens* (1-3) kommt vor. *N. striatus* ist — natürlich — anwesend. Ebenso kommen *N. garnieri*, *N. incrassatus* und *Operculinella*-Arten vor, *N. fabianii* ist aber *noch nicht* vorhanden. Auf Grund dieser Tatsachen wird dieser Horizont als Schlußhorizont des Mitteleozäns aufgefaßt.

Obereozän

Im Bakony-Gebirge besteht eine Kontinuität der Sedimentation, nur in den Randgebieten der ehemaligen Teilbecken können an der Grenze zwischen Mittel- und Obereozän Konglomerate bzw. Schotter-Bänke als Zeugen der präpyrenäischen Meeresbodenschwankungen beobachtet werden (z. B. bei Sümeg). Nach Osten hin gewinnen diese Bewegungen immer mehr an Bedeutung und im Budaer-Gebirge läßt sich schon eine gut ausgeprägte *Diskordanz und Abtragung* zwischen den Mittel- und den Obereozän-Bildungen feststellen. Diese Abtragung hatte z. B. in der Tiefbohrung Solymár-72 bis unter die *N. kovácsiensis*-Schichten hinuntergegriffen. Das war die *dritte Aushebungsphase* während des Eozäns und die nachfolgende *vierte Transgression* fand schon *im Obereozän* statt.

Eine detaillierte biostratigraphische Einteilung des Obereozäns im Transdanubischen Mittelgebirge läßt sich zur Zeit nur teilweise durchführen, z. T. weil die moderne paläontologische Bearbeitung noch im Gange ist, z. T. aber auch weil in vielen Profilen die obereozäne Schichtenreihe (infolge nacheozäner Denudation) fehlt.

Die folgenden Angaben über die Schichtenreihen von Halimba (3), Balinka (7), und Tatabánya (11) sind nur als vorläufige Mitteilungen anzusehen.

Im Gebiet von Halimba (3) ist das Obereozän durch eine *Discocyclinidenführende* Mergel- und Sandsteinserie mit vielen Andesittuffit-Zwischenlagerungen vertreten. Die Mächtigkeit der Schichtenfolge übersteigt die 300 m.

Bei Balinka (7) und Tatabánya (11) nehmen am Aufbau der Schichtengruppe auch Rotalgenkalke teil. Als die wichtigsten Großforaminiferen des Obereozäns von Balinka erwiesen sich *Operculinoiden*, einige Exemplare von *N. pulchellus*, *N. cf. variolarius*, *N. cf. incrassatus*, *Discocyclina angustae* und *N. wemmelensis*. Die Mächtigkeit beträgt 200 m.

Am besten kann der obereozäne sedimentäre Zyklus des Budaer-Gebirges gegliedert werden (15 — XIV-XVI, DUDICH 1957, 1959; DUDICH — MÉSZÁROS 1964).

XIV. *Nummulites fabianii- und Discocycliniden-führende Schichten*

Diese Bildungen sind transgressiv. An der Basis befinden sich stellenweise Brekzien bzw. Konglomerate, terrestrische rote Tone und Braunkohlenlinsen. Über ihnen folgen schon marine, z. T. sandige Kalksteine bzw. kalkige Sandsteine und Mergel, die *Nummulites fabianii* und viele Discocycliniden (in älteren Beschreibungen: Orthophragminen) und Rotalgen (aus dem Formenkreis der *Lithothamnien*) enthalten. *Echinoiden* und *Dekapoden* sind mit vielen Arten vertreten und auch *Korallen* und *Bryozoen* kommen vor. In der Tiefbohrung Solymár-72 wurden in obereozänen Kalksteingeröllen, die später umgelagert wurden, die ersten *Spiroclypeen* Ungarns gefunden.

XV. *Bryozoen-Mergel* (mittleres Glied des Obereozäns)

In den verschiedenen (Mergel- bzw. Kalkstein-) Fazies, die z. T. weiter fortschreitend transgredieren, kommt *N. fabianii* in geringerer Zahl vor, man trifft aber auch *N. budensis* Hantk., *N. incrassatus*, *Operculina cf. ammonea* an. Die numerisch wichtigsten Faunaelemente sind die *Bryozoen*, die *Korallen* büßen dagegen ihre Bedeutung ein. Neben den *Echinoiden* und *Dekapoden* treten einige *Brachiopoden* und *Crinoiden* auf. Es gibt auch eine artenreiche Kleinforaminiferenfauna (unter anderen *Hantkenina kochi*). Rotalgen sind manchenorts gesteinsbildend (»Lithothamnienkalke«).

XVI. *Budaer Mergel* (oberes Glied des Obereozäns)

Diese Bildung umfaßt den oberen, wiederum z. T. transgressiven, im allgemeinen schrittweise abnehmend kalkigen Teil des Mergelkomplexes.

Ob der Budaer (»Ofner«) Mergel den obersten Horizont des Eozäns oder schon den untersten des Oligozäns darstellt, wurde während der letzten 100 Jahre wiederholt diskutiert. Die häufig als Beweis für das oligozäne Alter zitierten »latdorfischen« Formen scheiden aus der Diskussion automatisch aus, weil das Lattorfien neuerdings ins Obereozän gestellt wurde (KRUTZSCH—LOTSCH 1958).

Sedimentologisch betrachtet, gehört der Budaer Mergel zweifellos dem obereozänen Sedimentzyklus an. Auch seine mikromineralogische Zusammensetzung spricht dafür (DUDICH 1958). Faunistisch ist der enge Zusammenhang mit dem Liegenden ganz klar. *Discocycliniden* sind etwas seltener, *Nummulites budensis* kommt noch vor, die *Bryozoen*-Zönosen sind etwas verändert, aber noch da. Die *Dekapoden* sind beinahe verschwunden. *Schnecken*, *Muscheln*, *Echiniden* und *Brachiopoden* treten in den Vordergrund. Zwei tuffitische Schichten enthalten massenhaft *Pteropoden*. In der Kleinforaminiferenfauna überwiegen die planktonischen Formen (besonders die *Globigeriniden*). Die Assoziation bildet den »6. Horizont« in der Einteilung von MAJZON (1960).

Die Sedimentation des Budaer-Gebirges zeigt einen Übergang vom Paläogen des Transdanubischen Mittelgebirges zu dem des nordöstlichen Teiles des Ungarischen Mittelgebirges. Sie entwickelt sich aus dem ersten, ist jedoch später, von der Eozän-Oligozän-Wende an, mit dem letzteren verbunden. Transdanubien wurde nämlich zu Ende des Obereozäns infolge der pyrenäischen Bewegungen kräftig angehoben, wobei die sog. infraoligozäne Denudation einsetzte. Der östliche Teil der Umgebung von Budapest blieb aber noch unter Wasser, und in diesem Gebiet kann eine ununterbrochene Fortsetzung der Sedimentation (vom Budaer Mergel z. T. durch die sog. Fazies von Tard zum rupelischen »Kisceller Tonmergel«, einer charakteristischen Ablagerung des oligozänen Meeres im nordöstlichen Ungarn) festgestellt werden. Keineswegs kann man aber den Budaer Mergel als eine dem Kisceller Tonmergel äquivalente Bildung *über* den Hárshegyer Sandstein und über die Fazies von Tard ins Oligozän stellen.

LITERATUR

1. ANDRUSOV, D.—KÖHLER, E.: Geologický Sbornik **XIV,** 175—192, 1963. — 2. BERTALAN, K.: Földt. Közl. 73—74, 47—55, 1947. — 3. BOMBIŢĂ, G.: Contribuţii al corelarea eocenului epicontinental în R. P. Romînă. — Edit. Acad. R. P. R., Bucureşti, 1963. — 4. BIEDA, F.: Instytut Geologiczny Prace Warszawa **XXXVII,** 216, 1963. — 5. DUDICH, E. JR.—MÉSZÁROS, N.: Neues Jb. Geol. Pal., Abh., **118,** 65—84, 1963. — 6. DUDICH, E. jr.: Földt. Közl., **87,** 211—214, 1957. — 7. DUDICH, E. jr.: Földt. Közl., **88,** 337—343, 1958. — 8. DUDICH, E. jr.: Annales Univ. Sci. Budapestiensis de L. Eötvös, Sec. Geol., **II,** 53—87, 1958. — 9. DUDICH, E. jr.—HŐRISZT, GY.: Földt. Közl. **94,** 10—26, 1964. — 10. DUDICH, E. jr.—MÉSZÁROS, N.: Mém. Bureau Rech. Géol. et Min., **28,** 685—705, 1964. — 11. GABRIELJAN, A.: Mém. Bureau Rech. Géol. et Min. **28,** 797—804, 1964. — 12. HANTKEN, M.: Math. és Term.-tud. Közl. **III,** 384—444, 1865. — 13. HANTKEN, M.: A Magy. Földt. Társ. Munk. **III,** 98—102, 1867. — 14. HANTKEN, M.: A Magy. Földt. Társ. Munk. **IV,** 48—56, 1868. — 15. HANTKEN, M.: Földt. Int. Évkönyve **I,** 1—141, 1871. — 16. HANTKEN, M.: Ért. a Term.-tud. Köréből **II,** 1—18,

1871. — 17. HANTKEN, M.: Földt. Közl. **4,** 198—202, 1874. — 18. HANTKEN, M.: Földt. Közl. **4,** 202—205, 1874. — 19. HANTKEN, M: Ért. a Term.-tud. Kör. **V,** 1—21, 1875. — 20. HANTKEN, M.: Esztergom megyei nummulitokról. A magy. orvosok és term.-vizsgálók 1876. évi munkálatai. Budapest, 1878, p. 119—122. — 21. HANTKEN, M.: Ért. a Term.-tud. Kör. **IX,** 12, 1—32, 1879. — 22. HANTKEN, M.: Földt. Közl. **10,** 41—52, 1880. — 23. HANTKEN, M.: Ért. a Term.-tud. Kör. **XIV,** 6, 1—52, 1884. — 24. HOFMANN, K.: Földt. Int. Évkönyve **I,** 199—273, 1871. — 25. HOFMANN, K.: Földt. Közl. **10,** 245—292, 1880. — 26. HOFMANN, K.: Földt. Közl. **14,** 174—190, 1884. — 27. HOTTINGER, L.—LEHMANN, R.—SCHAUB, H.: Mém. Bureau Rech. Géol. et Min. **28,** 611—652, 1964. — 28. KATSCHARAVA, I. V.—KATSCHARAVA, M. V.: Mém. Bureau Rech. Géol. et Min. **28,** 805—815, 1964. — 29. KECSKEMÉTI, T.: Földt. Közl. **93,** 356—362, 1963. — 30. KOCH, A.: Földt. Közl. **1,** 93—95, 1871. — 31. KOPEK, G.: Földt. Int. Évi Jel. az 1959. évről, 9—19, 1962. — 32. KOPEK, G.: Földt. Int. Évi Jel. az 1961. évről, 295—306, 1964. — 33. KOPEK, G.—KECSKEMÉTI, T.: Annales Hist.-nat. Mus. Nat. Hung. **53,** 51—65, 1961. — 34. KOPEK, G.—KECSKEMÉTI, T.: Földt. Közl. **94,** 340—348, 1964a. — 35. KOPEK, G.—KECSKEMÉTI, T.: Bányászati Lapok **97,** 828—830, 1964b. — 36. KOPEK, G.—KECSKEMÉTI, T.: Oberlutetische Transgression im nordöstlichen Bakony-Gebirge (im Druck). — 37. KRUTZSCH, W.—LOTSCH, D.: Ber. geol. Ges. DDR, **3,** 99—110, 1958. — 38. MAJZON, L.: Földt. Közl. **90,** 355—362, 1960. — 39. MUNTYÁN, I.: Földt. Közl. **94,** 143—144, 1964. — 40. NEMKOW, G. I.: Mém. Bureau Rech. Géol. et Min. **28,** 761—765, 1964. — 41. NEMKOW, G. I.—BARCHATOWA, N. N.: AN SSSR, Moskau—Leningrad, 124, 1961. — 42. ROZLOZSNIK, P.: Földt. Int. Évi Jel. 1920—23. évekről, 50—59, 1925. — 43. ROZLOZSNIK, P.: Földt. Int. Évi Jel. 1920—23. évekről, 80—88, 1925. — 44. ROZLOZSNIK, P.: Führer in Tatabánya. Führer Studienreisen Pal. Ges., Budapest, 1928. — 45. ROZLOZSNIK, P.: Führer in Ajka-Csingervölgy. Führer Studienreisen Pal. Ges. Budapest, 1928. — 46. ROZLOZSNIK, P.: Földt. Int. Évi Jel. 1925—28. évekről, 65—86, 1935. — 47. ROZLOZSNIK, P.—HANTKEN, M.—MADARÁSZ, Zs.: Földt. Szemle **I,** 159—189, 1964. — 48. ROZLOZSNIK, P.—SCHRÉTER, Z.—TELEGDI ROTH, K.: Az esztergomi szénterület bányaföldtani viszonyai. Budapest, 128, 1922. — 49. SCHAUB, H.: Schweiz. Pal. Abh., **68,** 222, 1951. — 50. SÓLYOM, F.: Földt. Int. Évi Jel. 1950. évről, 221—230, 1953. — 51. SZÖRÉNYI, E.: Felsőlutéciai korú tengeri sün fauna Iszkaszentgyörgyről (Bakony-hegység) (im Druck). — 52. SZŐTS, E.: Geol. Hung., Ser. Geol. **9,** 320. — 53. TAEGER, H.: Földt. Int. Évkönyve **XVII,** 1—256, 1909. — 54. TAEGER, H.: Összehasonlító megfigyelések a Déli-Bakony eocén rétegeiről. (In: Lóczy, L.: A Balaton tud. tanulmányozásának eredményei, I, **1,** 225—236, 1913. — (Das Eozän am Nordausgang des Balaton-Hochlandes.) Res. d. Wiss. Erf. d. Balatonsees, I, **1,** 264—275, 1916. — 55. TAEGER, H.: Geol. Hung., Ser. Geol. **6,** 128, 1936. — 56. TELEGDI ROTH, K.: Földt. Közl. **53,** 5—14, 1924.—57. TELEGDI ROTH, K.: Földt. Int. Évi Jel. 1920—23. évekről, 69—81, 1925. — 58. TELEGDI ROTH, K.: Földt. Közl. **57,** 32—41, 1928. — 59. TELEGDI ROTH, K.: Földt. Int. Évi Jel. 1925—28. évekről, 115—126, 1935. — 60. TOMOR-THIRRING, J.: Földt. Közl. **65,** 2—15, 1935. — 61. VADÁSZ, E.: Földt. Közl. **72,** 151—170, 1942. — 62. VADÁSZ, E.: Magyarország földtana. Edit. 2., Budapest, 1960. — 63. VITÁLIS, I.: Magyarország szénelőfordulásai. Sopron, 1939. — 64. VITÁLIS, I.: Bány. és Koh. Lapok **81,** 1948. — 65. ZITTEL, K.: Sitzungsber. Akad. Wiss., Wien, **XLVI,** 1862.

PROBLEMS OF EOCENE STRATIGRAPHY IN THE TRANSDANUBIAN MOUNTAINS, HUNGARY

By

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Abstract

The eocene sedimentation in Transdanubia was generally supposed to have been continuous. It has turned out, however, that it was interrupted by three phases of emersion followed by transgressions of increasing extension. In accordance with this fact also the brown coal-bearing formations differ in age. The authors have established a detailed biozonation based chiefly on the study of large Foraminifera in many boreholes. In 15 characteristic sections a total of 16 horizons are distinguished (Lower Ypresian through Upper Priabonian). These are discussed in stratigraphical order, with special regard to three marker horizons (those of N. laevigatus, N. perforatus and N. fabianii respectively) that render possible the correlation with the Eocene of other countries.

There is no marine Paleocene in the Transdanubian Mountains.

Lower Eocene

I. Horizon of Alveolina oblonga, with Alveolina cf. rütimeyeri, N. burdigalensis, N. partschi. In the upper beds, N.? "vetolaevigatus" n. sp.
First emersion (prior to the Lutetian)

Middle Eocene

II. Brown coal-bearing complex of Lower Lutetian age.
III. Horizon of N. laevigatus, with N. baconicus, N. sismondai, N. deshayesi and Alveolines.
Second, general emersion
IV. Horizon of the "intra-Lutetian denudation".
V—VIII. Brown coal-bearing terrestric, limnic and brackwater horizons, and the horizon of N. subplanulatus and N. kovácsiensis.
IX. Transitorial horizon, developed in three facies types.
X. Horizon of N. perforatus.
XI. Horizon of N. striatus (especially well developed in the N—E region).
XII. Horizon of N. millecaput.
XIII. Horizon of glauconitic marls with Discocyclinids.
Third (pre-Pyreneic) emersion (in the N—E territory only)

Upper Eocene

XIV. Horizon of N. fabianii with Discocyclinids and N. wemmelensis.
XV. Horizon of the "Bryozoan marl".
XVI. Horizon of the "Buda marl" with N. budensis. (Horizon N⁰ 6 of the small Foraminifera, according to L. MAJZON).

Pyreneic emersion, "infraoligocene denudation", except in the eastern surroundings of Budapest, where the sedimentation passed into the Oligocene without interruption.

СТРАТИГРАФИЧЕСКИЕ ПРОБЛЕМЫ ЭОЦЕНА ЗАДУНАЙСКОГО СРЕДНЕГОРЬЯ В ВЕНГРИИ

Г. КОПЕК, Т. КЕЧКЕМЕТИ и Э. ДУДИЧ МЛ.

Р е з ю м е

Установлено, что осадконакопление эоцена Задунайского Среднегорья, которое до настоящего времени считалось беспрерывным, происходило с перерывами. Оно было прервано тремя фазами регрессии моря, и после каждой из них следовала трансгрессия, которая охватывала все бóльшие территории. Соответственно этому, и возраст буроугольных отложений различный.

Авторы статьи разделили эоцен Задунайского Среднегорья на горизонты, на основе крупных фораминифер, которые были изучены по данным большого количества буровых скважин. В 15 характерных разрезах выделено всего XVI горизонтов (начиная с нижнеипрского и кончая с верхнеприабонским).

Эти горизонты описаны авторами по их стратиграфической последовательности, причем особое внимание было уделено трем главным (руководящим) горизонтам (N. laevigatus, N. perforatus, N. fabianii), которые дают возможность сравнить эоценовые отложения, залегающие на территории разных стран.

ZEICHENERKLÄRUNG

1 — Kalkstein

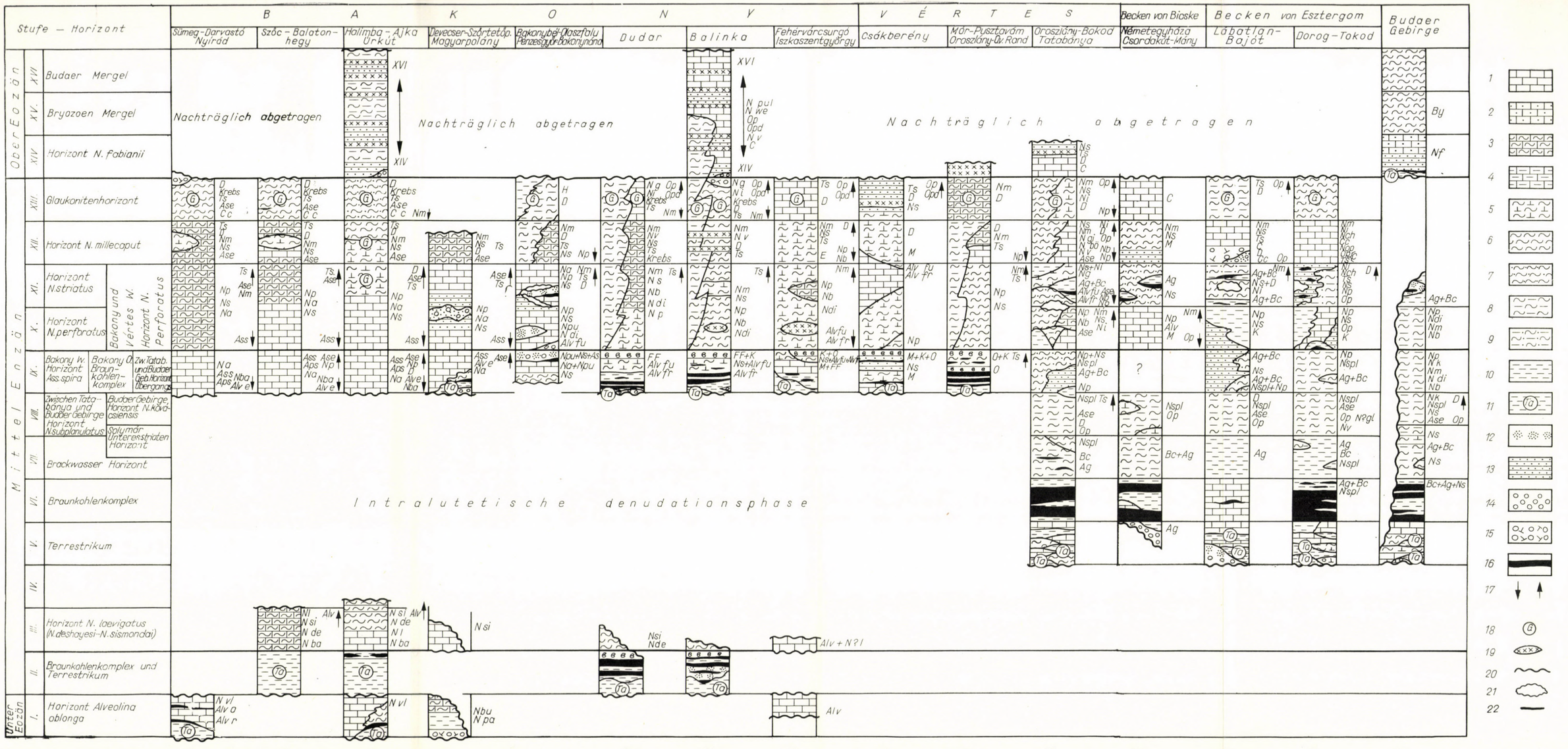
2 — Sandiger Kalkstein
3 — Mergeliger Kalkstein
4 — Toniger Kalkstein
5 — Kalkmergel
6 — Mergel
7 — Sandiger Mergel
8 — Tonmergel
9 — Sandiger Tonmergel
10 — Ton
11 — Bunter Ton
12 — Sand
13 — Sandstein
14 — Schotter
15 — Konglomerat
16 — Braunkohlenflöze
17 — Die Art kommt im unteren bzw. oberen Teile des Komplexes vor.
18 — Glaukonitgehalt
19 — Pyroklastite
20 — Diskordanz
21 — Örtliche Diskordanz
22 — Basis der Leithorizonte

Foraminiferen

Alv. e. = Alveolina elongata
Alv. fr. = A. fragilis
Alv. fu. = A. fusiformis
Alv. o. = A. oblonga
Alv. r. = A. rütimeyeri
Ase = Assilina exponens
Asp = A. praespira
Ass = A. spira
D = Discocyclina
H = Hantkenina
Na = Nummulites aturicus
N. b. = N. brongniarti
N. ba = N. baconicus
N. bi = N. biarritzensis
N. bö = N. böckhi
N. bu = N. burdigalensis
N. ch = N. chavannesi
N. di = N. discorbinus
N. f. = N. fabianii
N. g. = N. garnieri
N. gi = N. gisehensis
N. ? gl. = N. ? globulus
N. i. = N. incrassatus
N. k. = N. kovácsiensis
N. l. = N. laevigatus
N. m. = N. millecaput
N. op = N. operculiniformis
N. p. = N. perforatus
N. pa = N. partschi
N. pu = N. puschi
N. pul. = N. pulchellus
N. s. = N. striatus
N. si = N. sismondai
Nspl = N. subplanulatus
N. v. = N. variolarius
N. vl = N. ? »vetolaevigatus« n. sp.
N. we = N. wemmelensis
Op = Operculina
Opd = Operculinoides

Andere Faunaelemente

Ag = Anomia gregaria
Bc = Brachyodontes corrugatus
By = Bryozoa
C = Corallinacaea
Cc = Conoclypus canoideus
E = Echinoidea
K = Korallen
M = Miliolina
O = Ostrea roncana
Ts = Tubulostium spirulaeum
FF = »Fornaer« Fauna


Stufe – Horizont
Sümeg-Darvastó Nyírád
Szőc – Balaton-hegy
Halimba – Ajka Urkút
Devecser-Szörtetőp. Magyarpolány
Bakonybél-Oszfalu Pénzesgyőr-Bakonynána
Dudar
Balinka
Fehérvárcsurgó Iszkaszentgyörgy
Csákberény
Mór-Pusztavám Oroszlány-Ov. Rand
Oroszlány-Bokod Tatabánya
Becken von Bicske
Németegyháza Csordakút-Mány
Becken von Esztergom
Labatlan-Bajót
Dorog-Tokod
Budaer Gebirge
Nachträglich abgetragen
Intralutetische denudationsphase
Ober Eozän
Mittel Eozän
Unter Eozän
Budaer Mergel
Bryozoen Mergel
Horizont N. fabianii
Glaukonitenhorizont
Horizont N. millecaput
Horizont N.striatus
Horizont N.perforatus
Bakony Iv. Horizont Ass.spira
Zwischen Tatabánya und Budaer Gebirge
Horizont N.subplanulatus
Brackwasser Horizont
Braunkohlenkomplex
Terrestrikum
Horizont N. laevigatus (N.deshayesi-N.sismondai)
Braunkohlenkomplex und Terrestrikum
Horizont Alveolina oblonga
Bakony und Vértes W. Horizont N. perforatus
Bakony Ö. Braunkohlen-komplex
Budaer Gebirge, Horizont N.kövesiensis
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THE PROBLEMS OF DEPTH WATER RESERVE ECONOMY IN HUNGARY

By

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The drinking-water demands of Hungary are met with predominantly by deep drill-wells (artesian and subartesian). The first artesian wells were drilled 80—90 years ago. Today, the number of deep wells exceeds 34 000.

Merely a few explorers were interested in the problem of water reserve calculations (1—4) the reason being a favourable water supply of the Country. It is due to this fact that no nomenclature and methodology of water reserve economy or methods of calculation have been worked out as yet. Further the establishment, approval and registration of underground water reserves has not yet been regulated by decree.

With the help of numerous well-columns and production data, the Hungarian hydrogeology took a different course. Many sided elaboration of the numerous well data was employed to indicate the extent of producible dynamic water reserve according to areal units. The milestones of this road are: the Hydrogeological Atlas (7), the Hydrogeology and Water Supply of County Szolnok (5), and the Register of Deep Drill Wells of Hungary (6).

The conference of the working committee of the Provisional Geological Group of the Council for Mutual Economic Aid, held in March 1963 in Budapest with a view to the evaluation and registration of underground water reserves, set the direction for the further work on water reserve economy. The decisions passed there, at the same time, pointed out the exploration tasks of future years and the measures to be taken in the field of water reserve calculations and registration (8).

The first task was to establish the total volume of water-bearing layers within each hydrogeological areal unit, since with this knowledge it is possible to calculate the quantity of water filling the useful pore spaces. Which is designated by the Soviet nomenclature as the natural water reserve. The author completed this work to a depth of 500 m. The total thickness of porous layers in each section of 100 ms was established by averaging several hundreds of well logs according to areal units. This is represented in the echelon figures placed on the margin of Fig. 1. The volume of porous and karstic aquiferous formations in the Quaternary and Tertiary sediments within a depth range of 500 m on the territory of the whole country is — according to calculations by the author — 10 000 km^3, and the natural water reserve may be set — reckoning with a pore volume of 30% — at 3000 km^3.

The final aim in the field of water reserve calculation is a regional determination of the exploitable water reserve. In Hungary, however, this will be possible only if the detailed exploration work specified in the present study will be accomplished.

The recovery of water in Hungary is generally from the Quaternary Pleistocene and the Young Tertiary Levantine and the Upper Pannonian beds. Sarmatian limestones, Tortonian, Helvetian and Burdigalien sediments, further the Triassig carbonate formations, finally — as for example in the Salgótarján basin — the Upper Oligocene sandstone formations can also be taken into consideration.

Among these, the Pleistocene sediments are mainly the best and largest aquifers (9); the larger part of the Pannonian series has fine grained, less per-

meable water-bearing horizons. At places sandbeds of coarser grain occur in them. In Hungary the Upper Pannonian complex is a formation of the largest geological extent. It forms — with the exception of the central mountains and the northern Oligocene covering mountains — an uninterrupted basin sediment over the entire territory of the country.

On the whole, the Pannonian sediments are characteristically rather clayey, fine-grained, and are consequently poor in water in the northern part of Transdanubia and in the Great Plain, while they contain many thicker sand horizons of coarser grain in the southern part. Therefore this latter can be considered as richer in water.

The total volume of water-bearing layers of the individual hydrogeological areal units, and within them, how large is the quantity of the water filling or flowing through the useful pore spaces; i.e. what is the extent of the so-called natural water reserves of each areal units had to be determined. In order to decide this question it is necessary however to know the geometrical dimensions, depth position and physical characteristics of the water-bearing layers. The pore spaces depends on the shape, distribution and situation of rock grains. It largely decreases if the sand contains clayey particles or if it has different cementing materials.

However, merely a part of the water stored in the pores can be drawn off, since a certain quantity of water adheres, under the effect of molecular, capillary and adsorption forces, to the surface of the grains, forming a so-called hydrate coating. On account of this trapped water, the water discharge capacity of the water-bearing rock is diminished. The water-discharge capacity, or in other words the productive water reserve is equal to the difference between the pore space and the content of trapped water.

From the point of view of actual water discharge, however, one of the characteristics of the rock is the permeability, too.

The greater the permeability of an aquiferous formation, the more suitable it is to satisfy large-scale water needs. The latter is characterized, then by the coefficient of permability.

The value of the coefficient of permeability is determined in Hungary, until now, only in connection with a few water-prospecting wells and also in the course of hydrogeological examinations preceding certain large-scale drainage works. Such were the open-cut as at Bántapuszta (Várpalota), Visonta and Bükkábrány. Similar investigations in connection with the actual drilling for the discovery of water could not even be thought of, since these would considerably increase the duration of the time of completion and the expenses of the wells.

The experiences gained from the drilling of wells during the last ten years, however, show that enough information as to the relative value of permeability coefficient can be gathered from the value of the rate of the yield of specific

water yield, the latter being the water output related to a depression of one running metre (Q/s). In fact, the rate of the yield of specific water contains the filter resistance, too; this circumstance, however, becomes negligible in relative evaluation, since generally a single type of filter construction is in use here in Hungary.

The specific water output is also a good standard because it reflects not only the permeability of the material immediately surrounding the filter, but also the lithological changes in the water-bearing rocks within the radius of action and also the effects of eventual faults.

In Hungary, the specific water output of aquiferous formations with medium grain size is 20—60 l/m/rm, that of fine, small grain layers is less than 20 l/m/rm, that of coarse grain layers, however is larger than 60 l/m/rm and that of sandy pebble beds is more than 100 l/m/rm.

It is possible not only to conclude from the specific water output the pore space influencing the extent of the natural water reserve, but also it is useful in the determination of the production reserve, since the size of the natural supply completion in the first place on the permeability of the water-bearing rock.

In order to illustrate the differences in the thickness of deep aquifers and thus in the natural water reserve of an areal unit — depending of course, on the geological structure — the author studied well logs of several hundreds of wells. He grouped them according to hydrogeological regions in such a way that he added the porous beds thicker than 2—3 m according to 100 m horizons and averaged them according to areal units and these are finally presented in the echelon figures on the margin of the map of the areal unit in question (Fig. 1)

The hydrogeological regional units comprise of such areas which dispose of roughly identical water recovery possibilities.

The author has dealt, in the first place in the aquifers lying at depths down to 500 m.

On the uppermost stripe of the echelon figures, the aquiferous beds totalized within the section between 0 and 100 m are represented. Continuing downwards, the same are shown according to 100 m horizons down to a depth of 500 m. Being 100 m horizons in question, the sum of the porous horizons within the former also represents, at the same time, the percentage. To facilitate perception reading, the values of 25 and 50% are drawn with thin lines.

From the echelon figures representing the generalized sequence, the percentage of water-bearing horizons within each hydrogeological regional unit is well visible.

The average thickness of water-bearing horizons within the depth range of 500 m is marked in percentage by dotted lines.

The average specific water output values of the regional units are shown in the first square to the right of the axis of the echelon figures in five grades, —

the iron content of water, at the same time shown in two grades readable from the legend.

One may well perceive from the echelon figures the difference between the individual regional units in the constitution of the series and the total thickness of water-bearing layers. The figures also give an idea of the depth horizont along which the arenization was most intensive.

The total thickness of the porous layers, of course, may be brought into immediate relation with only the natural water reserve of the pores.

The average quantities and values represented may be utilized only for relative valuation, since they are suitable merely for a comparison of the orders of magnitude. To judge, for example, with the information regarding the present water yield, whether there is a hope to meet present or perceivable water demands with the aid of deep water-bearing formations within the area of the regional unit; in other words, whether the natural water reserve of the area — considering also the perceivable water demands — is inadequate or is surplus.

For a more accurate and even absolute valuation, the territory of the country has to be worked up in a similar way at least according to settlements. Today, this work for the most part is accomplished.

Over the whole territory of the country, within a depth range of 500 m, the volume of fissured, cavernous water-bearing formations of the Quaternary and Tertiary sedimentary complex — according to the above explained elaboration, i.e. calculations — represents a total of 10 000 km^3. Out of this the natural water reserve, including the trapped water and calculating with a pore space of 30%, constitutes about 3000 km^3 [8].

The natural water reserve determined in this way may be categorized according to the number and distances of wells, from which date the reserve had calculated. From the data it can be established that one part of the natural water reserve thus calculated is not only prognostical, but also it satisfies the demands of the categories C_1 and C_2, too. The water reserve may be included in the higher category if it is in the area of settlements or villages, and in the lower category if it is in the sparsely inhabited area lying between villages.

Beyond these, however, it would be necessary to know, for the perceivable planning, the quantity of exploitable depth water in the different hydrogeological regional units, i.e. to know the production reserve of each unit. Until today this problem was solved only in a few countries of small territory and of simple geological structure, and then too only with the aid of systematically accomplished detailed hydrogeological research.

According to our present knowledge, the size of the production reserve depends — apart from the thickness and horizontal extension of the water-bearing formation, further from its physical and hydraulical parameters — mostly on the boundary properties of the water-bearing layer: i.e. whether

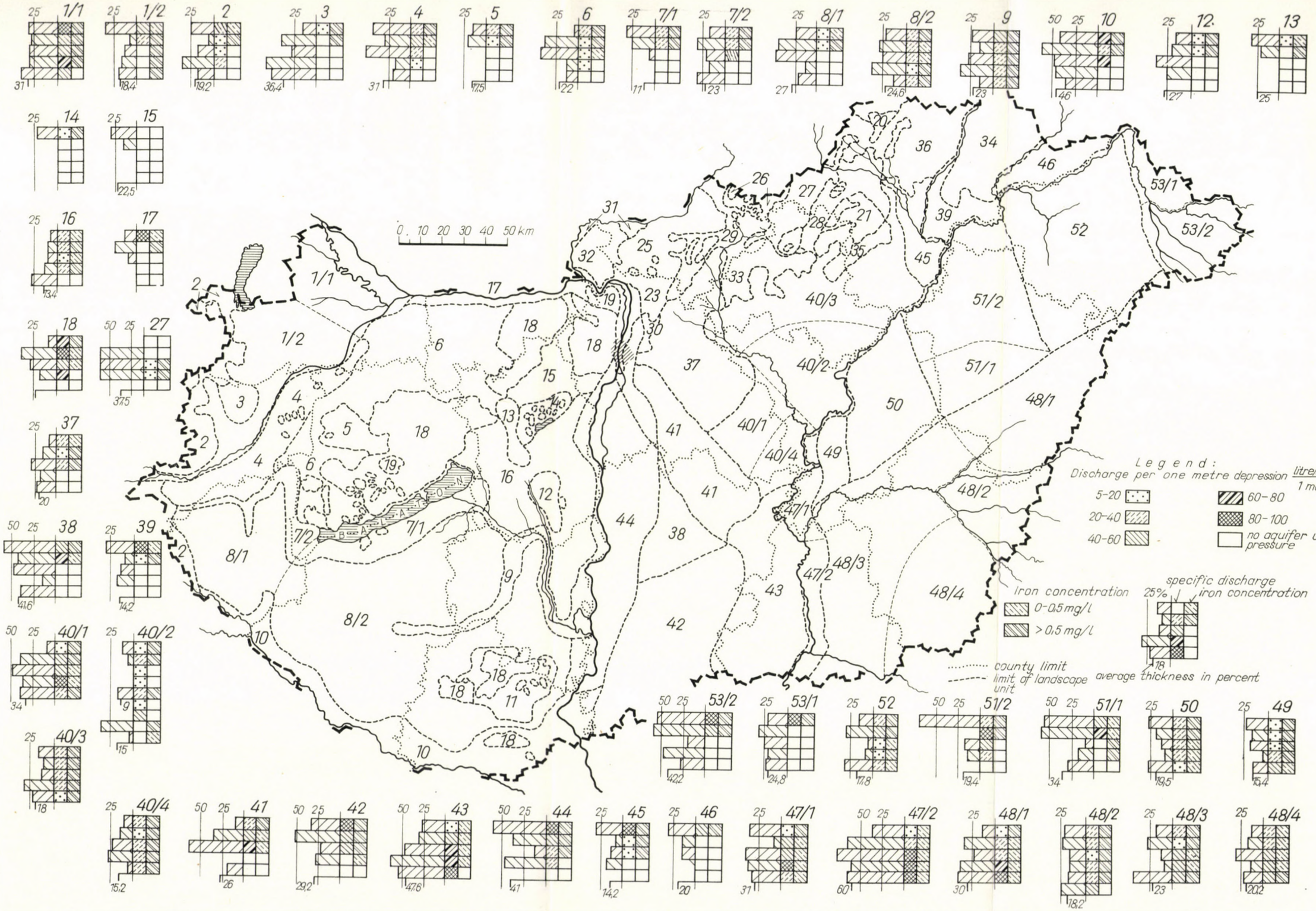

Fig. 1. Total thickness of water-bearing beds according to a depth classification from 0 to 500 m. Drawn by L. BÉLTEKY

the water-bearing formation is closed or otherwise, in the latter case, now large water supplies may be reckoned with, and from what distance.

The total thickness of the water-bearing layers of the series also influences the production water reserve of certain areas in a great measure, since a considerably larger water quantity can be produced with groups of two, three or eventually four wells planted for the beds lying at different depths, than from that water-bearing bed which appears as most suitable for water-winning according to statistical evaluation.

In view of the water output data of the registered wells that is based on cleaning and test pumping of 100—250 houres at most, no conclusions could be drawn as to the extent of water supply completion. The depth water supply completion may not be judged even from the grouped water production of water-works consisting of several wells, if there are no observation wells for the measurement of water-level depression.

On the basis of our present knowledge it must be stated that the production water reserve in a certain area may be determined solely by prospecting drilling and by test-pumping of the wells developed from these boreholes for the duration of several months or a year. Beyond this, of course, also the water regime of the area in question must be acquainted with by exploration, in order to make possible the planning of large-scale water-winning works of permanent service.

For the near future, akin to the underground water, the deep-seated water forms a further assignment for a network of extensive studies all over the nation. The supply of deep seated water in the various areas (under investigation) underlain by diverse geological formations, shall have to be tackled in the manner of a research problem, in the first place in the manner of domestic water. The porosity and permeability of the core samples obtained from the aquifers located in the rocks belonging to the Pleistocene and the Upper Pannonian, should be determined. Further a method has got to be worked out for the quantitative evaluation of the electrical loggings. If, later, these detailed investigations turn over material of appreciable quantity, then this may lead to the final objective of water storage and in turn to the regional establishment of a producing instrument.

REFERENCES

1. The Water Reserves of Hungary. I. Quantitative reckoning (in Hungarian). Publication by VITUKI, Budapest, 1954. — 2. JUHÁSZ, J.: Hidrológiai Közlöny, **1—2**, 21—34, 1954. — 3. UBELL, K.: Hidrológiai Közlöny, **2**, 94—104, 1962. — 4. JUHÁSZ, J.: Hidrológiai Közlöny, **4**, 283—292, 1962. — 5. URBANCSEK, J.: Hydrogeology and Water Supply of County Szolnok (in Hungarian), 1962. — 6. URBANCSEK, J.: The Register of Deep Drilled Wells of Hungary (in Hungarian), OVF, 1963. — 7. SCHMIDT, E. R.: Sketches and Studies to the Hydrogeological Atlas of Hungary MÁFI, 1962. — 8. BÉLTEKY, L.: The Problems of Depth Water Reserve Calculation in Hungary (in Hungarian), No. 4241 publication of MérnökiTovábbképző Intézet. — 9. RÓNAI, A.: Hidrológiai Közlöny, 378—390, 1963.

ВОПРОСЫ ПОДСЧЕТА ЗАПАСОВ ГЛУБИННЫХ ВОД В ВЕНГРИИ

Л. БЕЛТЕКИ

Р е з ю м е

Потребность в питьевой воде в Венгрии покрывается, в первую очередь, водой глубоких колодцев (артезианских и субартезианских). Первые артезианские колодцы были пройдены 80—90 лет тому назад, в настоящее время насчитывается около 34 000 артезианских колодцев.

Благоприятные условия водоснабжения в стране обясняют тот факт, что вопросами подсчета запасов вод занималось всего несколько исследователей (1—4). Этим связано и то что до настоящего времени еще не разработаны номенклатура и методика подсчета запасов вод, не существует метод подсчета и нет никакого постановления который урегулировал бы ределение, утверждение и учет запасов подземных вод.

Ввиду наличия большого числа профилей колодцев и данных о добыче венгерская гидрогеология развивалась другими путями и стремилась к тому чтобы на основе обработки имеющихся в распоряжении многочисленных данных по колодцам определить по каждому району динамические запасы воды. На этом пути важными достижениями являются изданный Гидрогеологический Атлас (7), дальше Гидрогеология и водоснабжение области Сольнок (5) и наконец катастер глубоких колодцев Венгрии (6).

Временная рабочая группа СЭВ по оценке и подсчету запасов глубинных вод — заседание которой происходило в Будапеште в марте 1963 года — разработала направления дальнейшего подсчета запасов вод, наметила задачи разведки в последующие годы и мероприятия необходимые в деле подсчета и учета запасов вод (8).

Первым заданием является определение всего объема водоносных горизонтов в одном гидрогеологическом районе, поскольку из этого можно вычислить количество воды, заполняющее полезный объем пор, называемое в советской номенклатуре естественными запасами вод. Автором эта работа была проведена до глубины 500 метров. Общая мощность пористых горизонтов по каждому 100 м автором определялась на основе расчета средней величины нескольких сот каротажных профилей по различным районам. Эти данные представлены ступенчатыми изображениями на рис. 1. На территории страны объем пористых и карстовых водоемов в свите отложений четвертичного и третичного периода до глубины 5000 м — согласно подсчетам автора — составляет 10 000 км³, а естественные запасы вод — при 30%-ном объеме пор — достигают 3000 км³.

Конечную цель подсчета запасов вод представляем региональное определение динамических запасов вод. Однако эту работу у нас можно начать лишь после проведения детальных поисковых работ перечисленных в данной статье.

SUBSURFACE WATERS IN DEEP QUATERNARY BASINS

By

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Deep Quaternary basins are important reservoirs of underground waters. The water that can be gained from any given reservoir depends on the grain size of the formation, on the permeable pore volume, and on the pressure existent in the reservoir. Anomalies are noticeable in the pressure distribution though Quaternary deposits chiefly of a fluvial origin form a system of communicating vessels (Fig. 3, 4, 5, 6). Progressing downwards at some places the pressure increases more rapidly, whereas at others the increase is slower when compared with the hydrostatically expected values of pressure. The anomalies may be explained by supposing that in coarse-grained deposits, such as gravel, water is exclusively under hydrostatic pressure, whereas in finer-grained deposits part of the load of the overburden is transferred to the water. In gravel layers the load of the overburden is wholly borne by the individual pebbles and is not transferred to the water contained in the pore volume.

The water yield of the strata depends consequently not only on the strata themselves but also on their location and their environment, in other words, the processes of sedimentation (Fig. 7, 8).

Regarding the quality of underground water, three depth zones can be distinguished in the Great Plains of Hungary. The uppermost ground water layer (first aquifer below the surface) generally contains a variety of salts in large quantities. The waters of the deeper-lying aquifers (below 50 metres) are more uniform and contain small quantities of dissolved salts in them. Two types are present: calcium hydrocarbonatic waters in the coarse deposits and sodium hydrocarbonatic waters in the finer-grained ones. At greater depths (1000 to 2000 metres) the water contained in the Lower Pannonian deposits is extremely rich in chloride and shows a sharp contact towards the waters higher up.

The knowledge of the hydrological conditions also helps in the study of the tectonics of the deep Quaternary basins.

The deep Quaternary basins filled with fresh-water deposits constitute, besides karst rocks, the best subsurface water reservoirs. In areas where surface water is scarce and karst water not available nearby, it is to these basins that one turns for an abundant supply of water fit for a variety of purposes. An area particularly well suited to the study of basins of this type is the Hungarian Basin, for one because of its vast area of nearly 100 000 sq.km, secondly because the depth of its individual Quaternary sub-basins locally exceeds 600 metres, and thirdly because the stratigraphy and hydrogeology of this region is well known on the basis of many thousands of artesian wells, the results of the study of which have been subjected to a detailed evaluation these last years.

The position of water in the Quaternary deposits

The Quaternary sub-basins of the Hungarian Basin are filled with largely fluvial deposits. The layers of proven aeolian origin are relatively insignificant whereas the fine-grained floodplain deposits, the sediments of waterlogged areas, swamps and marshes occur in considerable thicknesses.

The Quaternary deposits are completely saturated with water: there is no dry layer. Ground water begins at a depth of 3 to 4 metres below the sur-

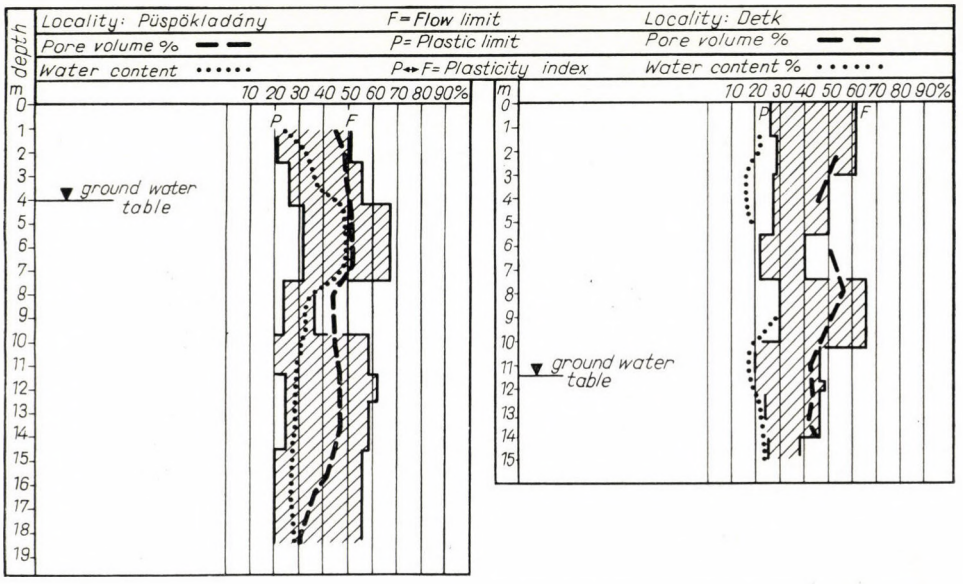

Fig. 1. Pore volume vs. moisture content in clays below the ground water table in the Great Hungarian Plain

Explanation. The plasticity of the clays traversed by the two borings is given in terms of the plastic limit and the flow limit. The plasticity index is indicated by the shaded area. Pore volume (dashed line) and water content (dotted line) are expressed in percents of the total volume

face, a depth of 10 to 15 metres being quite exceptional. On the other hand, a water table situated directly below the surface is a common occurrence over large areas. Also the uppermost few metres of the sedimentary series are frequently traversed by the oscillating ground water table on the one hand and the precipitations descending from above on the other. Under the ground water table there is observed a succession of permeable and impervious layers (Fig. 1).

The amount of water that can be extracted from a deposit is a function of the permeable pore volume rather than of the water content of the deposits in question. This is why in prospecting for water the layers of gravel and coarse

sand are principally looked for, because the permeable pore volume of these latter is larger than that of the fine sands, let alone that of the clays.

The quantity of the water furnished by a given layer is a function of the grain size distribution, that is, of the permeability of the sediment. However, factors other than the permeability also play a part. Calculations aimed at establishing subsurface water reserves on the basis of the porosity of the deposits do not yield reliable data except as a rough approximation averaging large areas. Locally other factors may also be essential in determining the available water resources of a sedimentary series, namely pressure, a parameter that increases with depth according to a relationship that is far from linear and uniform throughout. As predicted by hydrostatic theory, the pressure of subsurface water generally increases by roughly one atmosphere per ten metres of depth. Consequently, the static level of the water contained in the subsurface layers approximately coincides with the ground water table for most of the aquifers. This fact is further evidence in favour of the hypothesis that the permeable as well as impermeable layers of the Quaternary constitute a single huge reservoir in which the distribution of pressure is more or less uniform. There are, however, some exceptions to this rule. In a fairly large number of wells drilled in the Hungarian Plains, water pressure was found to increase by more than one atmosphere per ten metres of depth. The static level of these waters is consequently situated above the ground water table. In these wells the waters of the deeper-lying aquifers were found to rise 5 to 10, occasionally as much as 15 metres above the surface. For certain aquifers lying at depth greater than 1000 metres this excess pressure may correspond to a head of as much as 20 to 25 metres above the surface. In other words, the deeper the aquifer, the greater the excess pressure. On the other hand, in certain other regions the static level decreases with the increasing depth of the aquifer. With the water table not more than 3 to 4 metres below the surface, the static level of the waters contained in aquifers at 50 to 100 metres depth does not rise higher than 5 to 10 metres below the surface, and for aquifers situated between 200 and 250 metres this depression may attain 10 to 15 metres.

In the two figures below, the wells are arranged according to increasing depth. The slight undulations of the line connecting the static levels are due to the unevenness of the relief. Not all of the wellheads have been levelled: in consequence, the static level of the subsurface water is indicated in terms of level differences as measured from the surface rather than from any given datum level (Figs. 2, 3).

The excess pressure exhibited by the wells of the Cegléd area, increasing with depth, is termed here a positive pressure state whereas the gradual lowering of the static level with the increasing depth of the aquifer as observed in the Kecskemét wells is termed a negative pressure state. In literature one frequently encounters the statement that in the negative pressure state pres-

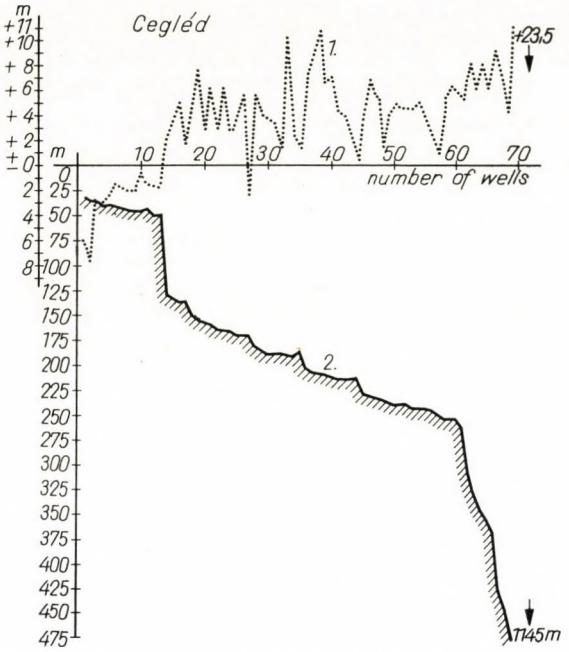

Fig. 2. Depth vs. static level of waters in the artesian wells of Cegléd

Explanation. Water levels and well depths are plotted to two different scales as the one is in the metre, the other in the hundred-metre range. 1. Dotted line: Static level of the wells below or above the surface. 2. Full line: Depth of the wells arranged in an increasing sequence

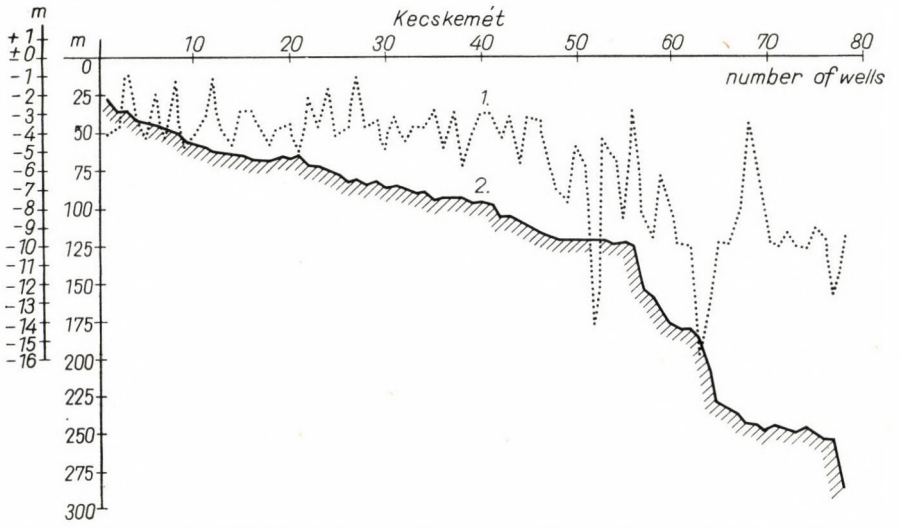

Fig. 3. Depth vs. static level of water in the artesian wells of Kecskemét
For explanations see Fig. 2

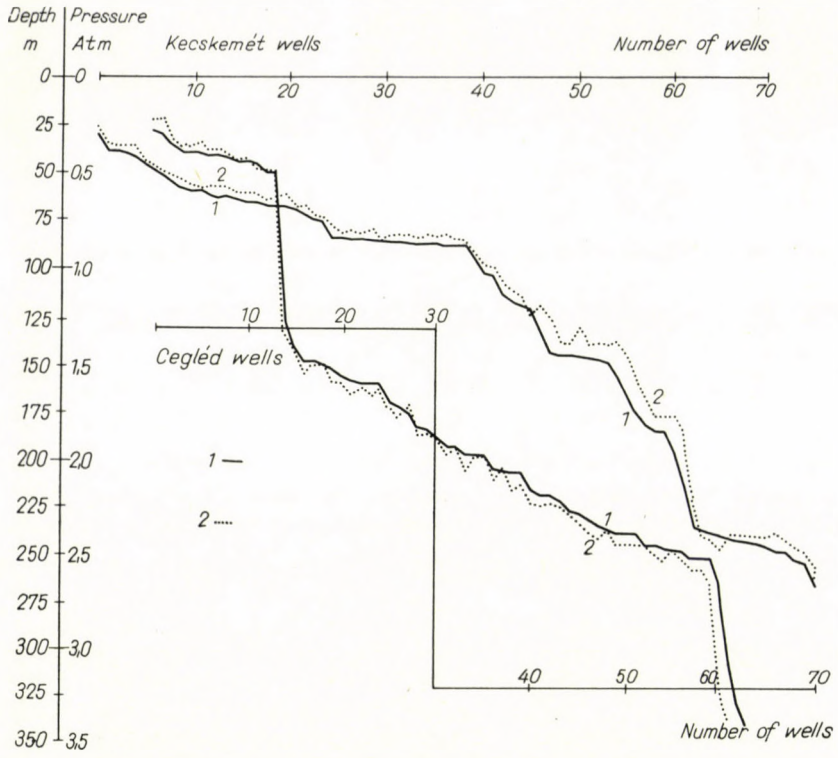

Fig. 4. Depth of wells vs. pressure acting upon underground water in the Cegléd and Kecskemét wells. Constructed by A. RÓNAI

Explanation. The two full lines (1—1) represent the depths of the wells as arranged in the order of increasing values. The starting point of one of the lines has been shifted in order to avoid the interference of the two lines. The two dotted lines (2—2) represent the pressure in atmospheres, as reflected by the static level, vs. the depth of the aquifer

sure actually decreases with depth. This is false. In the deeper wells the pressure is invariably greater: it is only the difference between the actual pressure and the pressure to be expected from hydrostatic theory that bears a negative sign in this state.

Depth vs. actual pressure as reflected by the static level of the aquifer is shown as Fig. 4. for the Cegléd and Kecskemét borings, chosen to represent the two contrasting types of region (Fig. 4).

The pressure acting on any body of subsurface water undoubtedly plays a role in determining the exploitable water supply contained in an aquifer. Consequently, the pressure anomalies also influence the discharge of the wells. On the other hand, as the pressure anomalies have been observed to be fairly

consistent over quite large areas, their causes must necessarily be connected with the structural and lithologic features of the Quaternary deposits.

It was found in a general way that the negative pressure state — i.e. the circumstance that pressure increases less rapidly with depth than predicted by hydrostatic theory — is invariably linked with the somewhat elevated parts of the Great Plains where the permeable sands covering the surface are underlain by a considerable thickness of coarse deposits (gravel and coarse sand). The positive pressure state coincides with the deeper-lying parts of the relief and with sedimentary columns mostly consisting of clay or fine sand with numerous interbeddings of clay (BALLÓ 1961, ALMÁSY 1962, RÓNAI 1963, URBANCSEK 1963).

The detailed study along several profiles of the lithology and of the pressure relations reveals that in the Quaternary deposits water is subjected to two kinds of influence. One is hydrostatic pressure increasing linearly with depth; the other is overburden pressure that, at least as far as its effect on the water content of the deposits is concerned, increases in a manner other than linear. Now water is contained in the pores of the deposit. If the deposit in question is coarse-grained such as gravel, the water in the pores is exclusively under the influence of hydrostatic pressure. It is the gravel grains that carry the full load of the overburden: in their interstices, water is free to move about independently of overburden pressure, just like in a system of communicating vessels. If on the other hand the aquifer consists of fine sand or sandy silt, part of the overburden pressure will be transmitted, according to my opinion, to the water in the interstices. This assumption is based, among others, on the experimental observation that the layer pressure tends to expel part of the water from the clay. The water included among the minute grains of clays bears the entire overburden pressure together with the clay particles. According to the above explanation this is the cause of the wide variety of pressure anomalies observed in our profiles (Fig. 5).

In the consistent occurrence of the positive and negative pressure state in certain areas another factor plays a part, namely the fact that the zones consisting of coarse gravel and sand, sand-covered also on the surface, emerge island-like as high as 20 to 25, locally even 50 to 100 metres from the surrounding regions. Consequently, the hydrostatic pressure in these regions is lower than in the depressions surrounded by more elevated areas.

The amount of water that can be extracted from a given layer depends on the grain size distribution and on the water pressure. The specific discharge, that is, the discharge obtained for unit depression, can be usefully employed in tracing coarse-grained deposits. In areas where the wells traverse many porous layers and the discharge of the wells is nevertheless poor, the connection with the areas of recharge is unsatisfactory and a negative pressure state prevails.

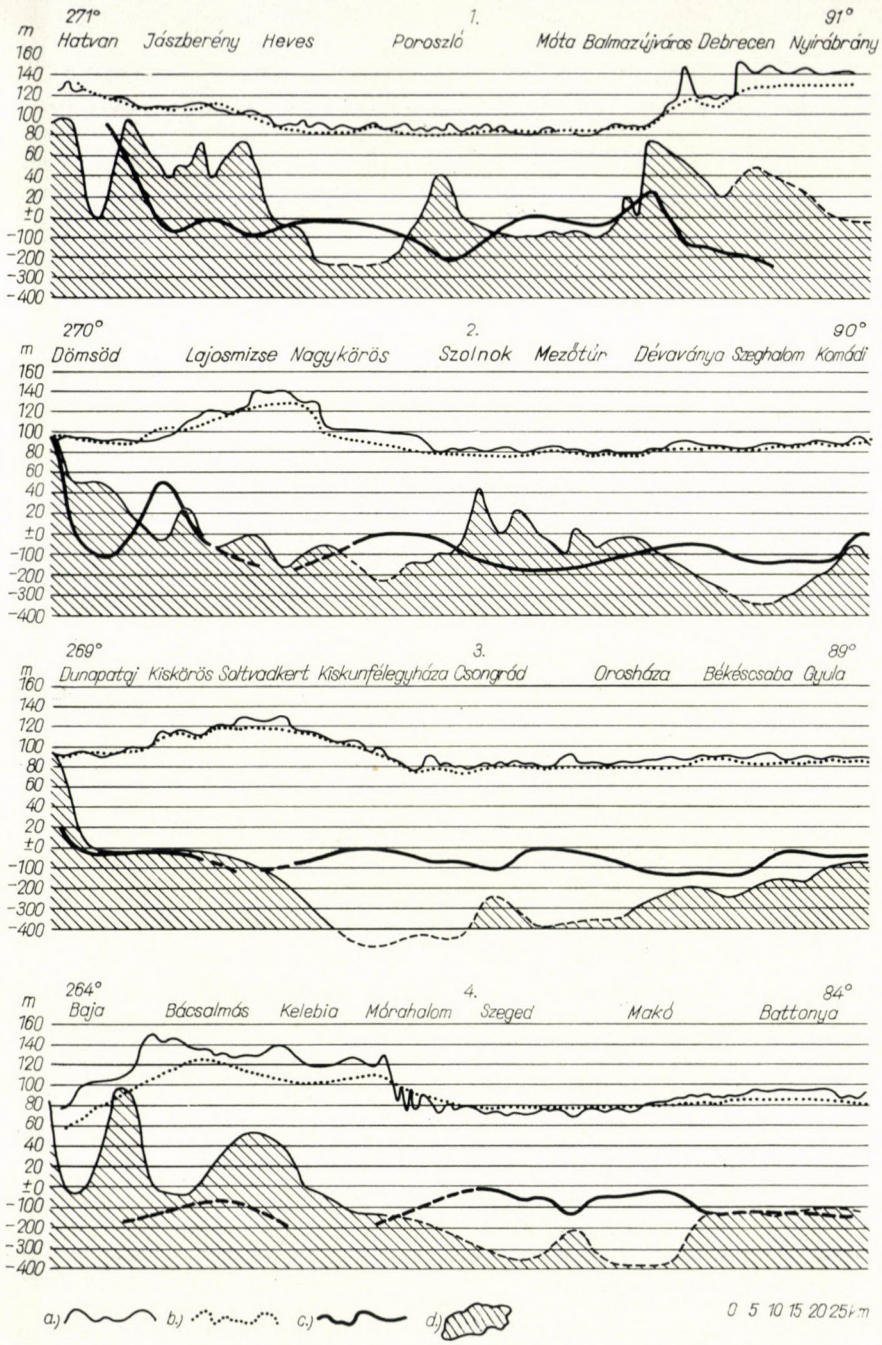

Fig. 5. General profiles representing the distribution of pressure in the underground waters in the Great Hungarian Plain. Constructed by A. RÓNAI in 1964

a) Surface
b) Line indicating the static level of water disclosed at sea level
c) Depth of the aquifers yielding water rising above the surface
d) Floor of the Quaternary fluvial deposits (Upper Pliocene clay and sand)

Gases also posses a pressure-elevating effect. In the Hungarian Plains, methane-bearing waters were disclosed by wells not deeper than a couple of hundred metres.

The discharge substantially depends, besides the natural factors, also on the design, construction and maintenance of the wells. It is a sequel of this circumstance that the graphs and maps constructed on the basis of discharge data must not be relied upon except if all these factors have duly been taken into account.

The effective discharge of the wells grouped according to regions and depth intervals is shown as Fig. 6 along the above-mentioned profiles. The

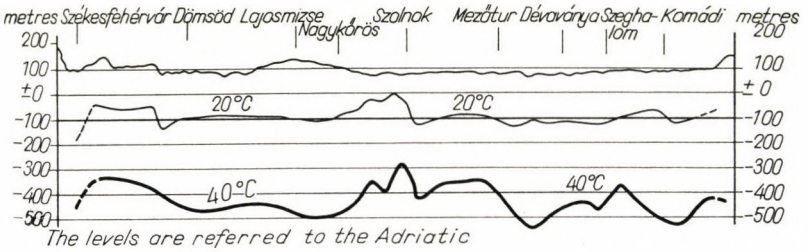

Fig. 7. Temperature of artesian waters in the Great Plains along an east-west profile. Constructed by A. RÓNAI.

Explanation. Besides those of the artesian wells, also the temperature data of wells drilled for hydrocarbons have been taken into consideration

data employed represent the best-known, most thoroughly studied and documented wells (Fig. 6).

The temperature of the well water reflects, on the one hand, certain natural geothermal influences; on the other hand, it depends on the construction of the well and in some cases also on the junction of several aquifers. The geothermic anomalies on the deep of the Hungarian Plains are well known. Fig. 7 serves to present the water temperatures measured in the wells.

In the Hungarian Plains even the quality of the high- and low-pressure subsurface waters is different. In the Plains, the uppermost layer of the ground water constitutes in itself a category apart. Under the dry, warm climate, capricious in the distribution of precipitation as well as in its temperature, a salty zone of evaporation comes to exist in the uppermost few metres under the ground water table. The first aquifer below the surface generally contains 1000 to 2000 milligrams of dissolved salts per litre on the average, but the concentration may locally rise as high as 5 to 10 or even 50 grams per litre (Jászkarajenő). The salts contained in these concentrated solutions vary from one region to the other: $NaHCO_3$, Na_2SO_4, $MgSO_4$, NaCl; but in many water samples the ions of four-five salts may be mixed together, sometimes in almost identical proportions and always in considerable concentrations (Fig. 8).

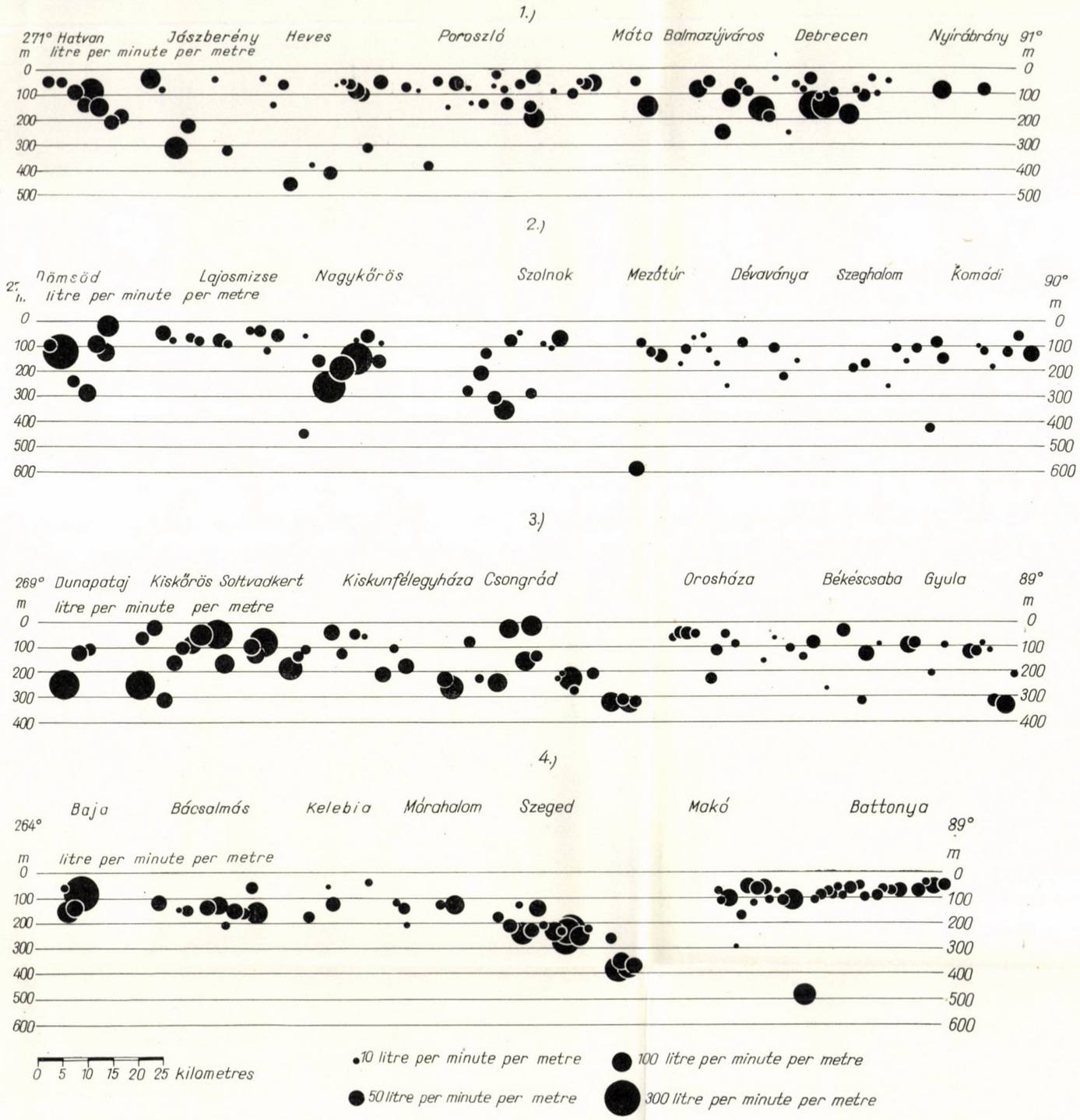

Fig. 6. Discharge capacity of wells of different depths along four profiles in the Great Plains. Constructed by A. RÓNAI.
Explanation. The diameter of the circles is proportional to the specific discharge of the wells (that is, to the discharge per unit depression)

A TALAJVÍZ ÉS FELSZÍN ALATTI KÜLÖNBÖZŐ MÉLYSÉGŰ RÉTEGEK VIZÉNEK KÉMIAI JELLEGE A MAGYAR ALFÖLD TERÜLETÉN EGY NYUGAT-KELET IRÁNYÚ SZELVÉNY MENTÉN

SZERKESZTETTE : DR. RÓNAI ANDRÁS

1964

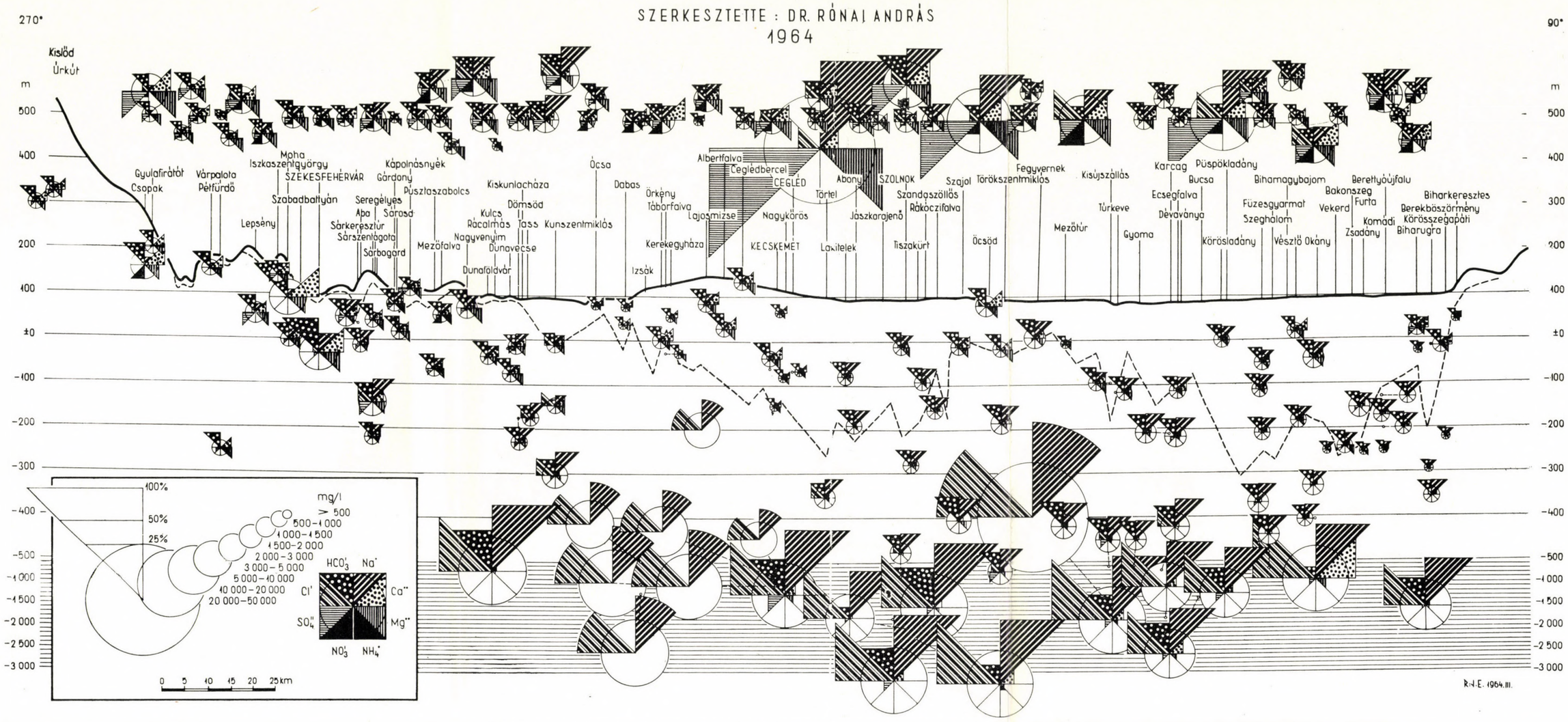

Fig. 8. Chemical features of the waters derived from aquifers at different depths in the Great Plains.
Constructed by A. RÓNAI in 1964.

Explanation

The diagrams represent the analysis results of waters derived from different depths. The diameters of the circles are proportional to the concentration of the dissolved salts. The four principal cations have been shown on the right side, the four principal anions on the left side of the circle, as rectangular triangles. The area of each triangle is proportional to the mole percentage of the corresponding ion. The heavy line across the figure represents the surface, the dashed one is the floor of the Quaternary fluvial deposits. The chemical composition of the uppermost layer of ground water in the Great Plains substantially differs from that of the deeper levels. The analysis results of the water samples from 3 to 10 metres depth have consequently been plotted in one line above the surface, above the names of the corresponding localities

The chemical character of this near-surface water layer is decisively influenced by local factors. The case of the deeper-lying Quaternary aquifers is entirely different. Beyond a depth of 30 to 50 metres the salt content of the waters contained in the Quaternary aquifers exhibits a sudden decreas (300 to 600 milligrams per litre). Also the variety of dissolved salts ceases and essentially two main types of chemical composition are present in the deeper Quaternary layers. The one is a calcium hydrocarbonatic type, related to the waters of the surface streams, rivers, springs and upland ground waters, the other is sodium hydrocarbonatic, that is, related to the waters of the soda lakes of arid areas.

The calcium hydrocarbonatic waters mostly occur in the coarse-grained aquifers easily reached by surface waters (mostly in the areas of negative pressure state). The sodium hydrocarbonatic waters mostly exist in the fine-grained aquifers, in the layers where the water moves but little, recharge is slow and part of the water is a soda-rich fossil water included in the alkali floodplain deposits. This water type is related to the Upper Pliocene, Upper Pannonian waters occurring in the layers underlying the Quaternary in the Great Plains basin. The water contained in these older layers is somewhat more concentrated, however. Below the Quaternary layers the salt content begins to increase again.

REFERENCES

ALMÁSSY, E.: Vázlatok és tanulmányok Magyarország Vízföldtani Atlaszához. (Sketches and Studies to the Hydrogeological Atlas of Hungary.) Magyar Állami Földtani Intézet, Budapest, 23—46, 1962. — BALLÓ, I.: Vízügyi Közlemények **43,** 482—499, 1961. — BÉLTEKY, L.: Magyarország vízföldtani atlasza. (The hydrogeological atlas of Hungary.) Magyar Állami Földtani Intézet, 40, 1962, Budapest. — RÓNAI, A.: Magyar Állami Földtani Intézet Évkönyve, **XLVI.** Fasc. 1, 1956. — RÓNAI, A.: Geologické Práce **59,** 161—214, 1960. — RÓNAI, A.: Hidrológiai Közlöny **43,** 378—391, 1963. — SCHMIDT, E. R.: Magyarország Vízföldtani Atlasza and Vázlatok és Tanulmányok Magyarország Vízföldtani Atlaszához. (cf. Almássy and Bélteky.) —SÜMEGHY, J.: Magyarország talajvízviszonyai. Budapest, Mérnöki Továbbképző Tanfolyam, 1954. — UBELL, K.: Vízügyi Közlemények **41,** 185—251, 1959. — URBANCSEK, J.: Hidrológiai Közlöny **40,** 398—403, 1960. — URBANCSEK, J.: Szolnok megye vízföldtana és vízellátása. (The Hydrogeology and Water Supply of Szolnok County.) Szolnok Megyei Tanács, Szolnok 1962. — URBANCSEK, J.: Hidrológiai Közlöny **43,** 205—218, 1963.

РАСПОЛОЖЕНИЕ ПОДЗЕМНЫХ ВОД В ГЛУБОКИХ ЧЕТВЕРТИЧНЫХ БАССЕЙНАХ

А. РОНАИ

Резюме

Глубокие четвертичные бассейны являются важными резервуарами подземных вод. Количество забираемой воды зависит от гранулометрического состава осадков, объема свободных пор и трещин и условий напора, существующих в пластах. В отношении распределения напора можно наблюдать аномалии несмотря на то, что четвертичные отложения главным образом речного происхождения образуют сплошную систему

сосуд (рис. 3, 4, 5, 6). В некоторых местах по мере увеличения глубины напор увеличивается сильное, чем предполагалось бы на основании распределения гидростатического напора, в других местах же он увеличивается в меньшей мере. Аномалии обусловлены тем, что в грубозернистых осадках (гальки) вода находятся только под гидростатическим напором, в то время как в более тонкозернистых пластах на воду влияет также и пластовое давление. В гравелистых пластах пластовое давление воспринимается полностью зернами гравия, а на воду, содержащуюся в их промежутках оно не оказывает влияния.

Водоотдача пластов — в соответствии с вышеизложенными соображениями — зависит не только от водоносных пластов самих, а также от их положения и окружающей их среды, значит, и от процессов седиментации (рис. 7 и 8).

В отношении качества подземных вод на территории Большой Венгерской Низменности можно выделить три глубинных зоны. Самая верхняя зона, это зона грунтовых вод (от первого водоносного горизонта под дневной поверхностью), которая обычно содержит весьма разнообразные виды соли. Более глубоко залегающие пластовые воды (ниже глубины 50 м) представляют собой более однообразный тип и содержат мало растворенных солей. Здесь выделяются два типа: в грубозернистых осадках — воды с гидрогенкарбонатом кальция, в мелкозернистых осадках — воды с гидрогенкарбонатом натрия. Еще глубже (в зоне глубин от 1000 до 2000 м) в нижнепаннонских отложениях встречаются воды с поваренной солью, отделяющиеся резкой границей от вышележащего водоносного горизонта.

Знание гидрологических условий оказывает определенную помощь также в изучении структурных особенностей глубоких бассейнов.

HYDROGEOLOGICAL CONDITIONS IN HUNGARY

By

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Subsurface water resources of Hungary are highly varied both as to quality and volume. The appreciation and mapping of these resources has lately been given considerable attention (see literature in footnote).*

The author gives a brief review of the demands and resources, with a geological sketch of the country enumerating the nature of the deposits, the nature of the water contained in them, the thickness of the aquifers, the distribution of the geothermal gradients, the pressure and current distribution in the underground aquifers, and the areas of recharge.

On the basis of the above considerations the author puts forward the proposition of evaluating the hydrogeological features of the Carpatho-Balkanic region according to unified principles and to clarify the problems of recharge, indispensable to any planned water economy.

Demands and resources. The underground water resources of Hungary are estimated at the following values, in categories:

Uppermost ground water aquifer (not under pressure): recharge 40, present extraction 4 to 5 cu. metre per sec.

Karst water: recharge 10 to 11, present extraction 3 to 4 cu. metre per sec.

Artesian water (under pressure): recharge 40, present extraction 10 to 13 cu. metre per sec. That is, the dynamic resource known at present (the constantly recharged resource that can be taken out without depletion of the resources) is 90 to 100 cu. metres per sec, as contrary to the present utilization of 17 to 22 cu. metres per sec.

Dynamic resources known at present meet demands until the turn of the century. By that time, however, the increase in population and the increasing

* SCHMIDT et al., Magyarország Vízföldtani Atlasza (The Hydrogeological Atlas of Hungary, with 73 maps), and Vázlatok és tanulmányok Magyarország vízföldtani atlaszához (Sketches and memoirs on Hungary's Hydro-Geological Atlas), 1962; RÓNAI, A magyar medencék talajvizei (The ground waters of the Hungarian basins), Földtani Intézet Évkönyve **46**, 1956; Magyarország vízkészlete, I. Mennyiségi számbavétel (Water resources of Hungary: I, Quantitative Assay), Edited by VITUKI, 1954, with 25 annexes. In previous times work was summed up in TELEGDI RÓTH: Magyarországi és erdélyi ásványolaj- és földgázkutató és termelő fúrásokkal fakasztott vizek vegyi összetétele (Chemical composition of waters found in research and productive oil and gas wells in Hungary and Transylvania), Földtani Közlöny, **80**, 17—98, 1950; SZÁDECZKY-KARDOSS: A nagyalföldi artézi vizek főtípusai és azok szintjelző értéke (Principal types of artesian water in the Great Hungarian Plains and their value in strata correlation), Bányászati és Kohászati Lapok **74**, 305—308, 1941, SCHMIDT, E. R.: Ipari vízproblémák Budapest déli szomszédságában (Problems of industrial water supply south of Budapest), **68**, 369—376, 1935.

demands per capita will have augmented to the ground water requirements of about 100 cu. metres per sec.

A few years back irrigation water demands of agriculture were insignificant. To-day these demands have tremendously increased.

In 1962 the irrigation of 200,000 cadastral acres* was initiated. By 1965 this surface increased to 570,000 cadastral acres; the project is 2 million for 1980 and 3.5 million for the turn of the century. This means following will be the water requirements in thousand million cu. metres per year:

0.4 in 1962, 1.0 in 1965, 3.0 in 1980 and about 5 in 2000. That is, in the above order, 12, 32, 98 and 160 cu. metres per sec., respectively.

The increasing demands for water force the hydrogeologists — due to the lack of appropriate amounts of sterile near-surface water — to turn to the aquifers of the thick basin sediment series. In order to exploit them it is essential to know the nature of the diverse aquifers as determined by the sediment, the temperature and the involved pressure respectively.

A brief review of the deposits follows

Quaternary. Terrestrial: gravel, sand, little clay. The water is of the calcium hydrogen carbonate type, having less than 20 German degrees of hardness and less than 1 gram per litre of dissolved matter.

Upper Pliocene: limnic, fluvial Sand, little gravel, lignite, clayey sand, clay. The chemical character of the water in this formation is ill-defined. Towards the top it resembles the Quaternary, while near the bottom it simulates the Upper Pannonian. Stratigraphically the deposit is none the less ill-defined. Dissolved matter is less than 1.5 gram per litre, slightly more than that in the Quaternary. Hardness is up to 15 German degrees.

Upper Pannonian. Fluvial, brackish: sands and clays. The water is of the calcium hydrogen carbonate type. However, in the course of its migration towards the centre and the deeper parts of the basin, it gradually passes into a sodium hydrogen type of water by the exchange of cation, that is, it becomes soft and sodic. Dissolved matter less than 2 grams per litre, hardness from 5 to 15 German degrees.

Lower Pannonian. Brackish. Sands, clays, clay marls. Sodium hydrogen carbonate and sodium chloride type waters. Dissolved matter from 10 to 20 grams per litre. Hardness between 10 and 20 German degrees.

Sarmatian. Brackish. Coarsely porous limestone, marl, rhyolite tuff, with calcium-magnesium hydrogen carbonate type water. Dissolved matter less than 13 grams per litre. Hardness from 5 to 10 German degrees. In limestone, there is little dissolved matter.

* One cadastral acre is about equal to 1.42 US acre.

Mediterranean I. and II. Marine. Leitha limestone, marl, volcanic tuff. Water containing calcium-magnesium hydrogen carbonate and sodium chloride. Dissolved matter is less than 25 grams per litre.

Oligocene. Marine. Clays, clay marls, sandstones, volcanic tuffs. Water containing sodium hydrogen carbonate, rich in sodium chloride (sodium sulfate in the north). Total salinity up to 30 grams per litre, hardness between 20 and 25 German degrees.

Eocene. Terrestrial, brackish, marine. Less thoroughly known. Limestones conglomerates, marls. Water supply is possible where it is underlain by Triassic carbonatic rocks. The chemical composition of the water resembles that of the Triassic.

Cretaceous and Jurassic: less significant. Marls and calcareous sandstones, otherwise is similar to the Triassic.

Triassic: marine; Hauptdolomite and Dachstein limestone, water containing calcium and magnesium hydrogen carbonate; hardness between 15 and 20 German degrees (between 20 and 40 at Budapest). Dissolved matter less than 3 grams per litre.

Crystalline basement: contains little water. Salinity seldom exceeds 0.5 gram per litre. The water is generally soft, in carbonatic rocks it is of the calcium hydrogen carbonatic type.

The salinity of the aforementioned waters generally exhibits a tendency to increase with depth. Most of the waters are to be considered as fossil water. Exceptions to the rule are the calcareous Sarmatian and the Triassic. In the course of diagenesis the original water content was expelled from them. The water contained in them at present is secondary (karst water).

SUESS's theory concerning juvenile waters and the implied vertical migration of water do not hold good in the Hungarian Basins. If it were true, the differences between the chemical composition of the waters in the individual aquifers ought to have disappeared long ago. The fact is, however, that the chemical composition of the water in any deposit has an almost-stratigraphic value.

The character of the waters may substantially be influenced by local factors. Thus e.g. between Budapest and Szeged Quaternary waters contain abundant magnesium sulfate. This is due to the circumstance that the Danube laid down in this stretch of region considerable quantities of dolomite eroded from its mountainous section. A water rich in sodium chloride may in the presence of CO_2 and in the vicinity of carbonatic rocks turn into a water of sodium hydrogen carbonate tpye, as e.g. in the Bükk Mountains. In the vicinity of the Oroszlány coal mine on the northeastern side of the Vértes Mountains there is some very soft water. This is also due to high CO_2 content. Iodine and bromine in sodium hydrogen carbonate type waters often implies the presence of oil structures. Interesting information as to the origin of subsurface waters is provided by heavy-water, studies in respect of the abundance of deu-

terium oxide (D_2O). As sea water is the only medium where deuterium oxide is enriched, excess D_2O in the Artesian waters of the Hungarian Tertiary strata indicates the water to be a fossil sea water.

The D_2O content of water ranges from 2.3 to 3.0 gamma. One gamma is one thousandth of one gram.

Water containing 1.8 gamma of D_2O was found at a depth of 730 meters; at Békés in Levantine layers.

At Hajduszoboszló, in Upper Pannonian deposits, water containing 2.6 gamma was found at 1090 metres.

Water containing 2.7 gamma was found at Cserkeszöllő, in the Lower Pannonian at a depth of 2311 meters and at Nagylengyel, in Tortonian at a depth of 2100 meters, resp.

Water containing 3.0 gamma, at Debrecen, where the uncased well section below 1611 metres traversed Rupelian deposits, but most of the water is from the Pannonian.

Thickness and temperature of deposits. In order to find thermal water today it is usual to drill deeper than 2000 metres. The tickness of the individual geological formations is as follows (maximum values): Quaternary, 250 metres, Upper Pliocene, 800 metres, Upper Pannonian, 1000 metres, Lower Pannonian 1000 metres, Miocene, 2400 metres, Oligocene, 1000 metres, Eocene, 400 metres.

Nature and value of the water is substantially influenced also by its temperature. On the basis of several hundred temperature measurements of the well-bottom, the following geothermal gradient values have been established for Hungary:

Great Plains, east of the Danube: 18 metres per degree Centigrade.

Transdanubia, west of the Danube, 20—24 m/deg. C.

North Hungary: Oligocene and Miocene not overlain by Pannonian: 23 to 26 m/deg. C.

In Hungary the geothermal gradient is thus seen to be less than one half to one third of the mean European gradient.

Experience permits to foretell to a fair degree of accuracy the depth to which a boring has to be sunk to yield water of a pre-determined composition and temperature. Actual findings generally tend to confirm prognostics of this nature.

Pressure in subsurface water and recharge areas. In the Great Plains, pressure acting upon subsurface water varies both horizontally and vertically. It is this pressure difference that determines among others flow directions in the areas of recharge of underground aquifers.

In the case of a hydrostatic pressure state, pressure at a given depth is proportional to the height of the water column above that depth. In the case of a positive pressure state pressure increases at a faster rate, in the case of a negative pressure state at a slower rate than in the hydrostatic case. Further-

more there are instances when the pressure of artesian water actually decreases with depth. It is simplest to measure the pressure of subsurface water by its static pressure, making allowances for changes in density due to warming up at depth and to gas content, if any. In drillings of the same depth, static level is slightly higher in areas of a positive pressure state and slightly lower in areas of negative pressure state than in areas of hydrostatic state.

Maps constructed on the basis of more than 1000 wells, profiles of equipotential surfaces and maps of contours connecting strata of identical static water level, clearly show the involved pressure relationships of the subsurface waters and also indicate *the areas of recharge of the individual aquifers*. Such areas are:

the Mátra Mountains, whose fissured volcanics, recharge the deeper-lying aquifers of the Great Plains;

the Bükk Mountains, whose carbonatic rocks, recharge by way of their karst cavities and fault systems the Great Plains aquifers;

the Nyírség area, whose porous, highly permeable sands, recharge the shallow aquifers of the Great Plains;

the southern part of the divide between the Danube and the Tisza, plays a role similar to that of the Nyírség.

It will not be possible to solve definitely the problem of the recharge of the artesian wells in the Great Plains until the hydrogeological relationships and features of the Carpatho-Balkanic region as a whole are not clarified according to unified principles. This region is the natural cadre of the large regional hydrogeologic unit of the Carpathian Basins.

ГИДРОГЕОЛОГИЧЕСКИЕ УСЛОВИЯ ВЕНГРИИ

Э. Р. ШМИДТ

Р е з ю м е

Запасы подземных вод Венгрии весьма разнообразны по количеству и качеству. В последнее время уделяется большое внимание их подсчету и изображению на картах.

Потребности и запасы. Подсчитанные запасы в категориях карстовых, грунтовых и артезианских вод. Общее количество запасов подземных вод составляет 90—100 м³/сек, в настоящее время откачивается около 17—22 м³ в секунду. Динамические запасы будут покрывать быстро растущие потребности примерно до конца настоящего столетия.

Геологический обзор Венгрии дается главным образом с точки зрения тектоники и истории геологического развития рассматриваемых геологических образований.

Краткая характеристика осадков и характеры вод отдельных образований. Соленость подземных вод обычно увеличивается с глубиной. Химизм вод отражает генетические условия (террестрические, солоноватоводные, морские) вмещающих пород, следовательно, это ископаемые воды. Исключением является только вода сарматских известняков солоноватоводного происхождения и триасовых (мезозойских вообще) известняков и доломитов морского происхождения. Из этих толщ при диагенезе осадков первичные, соленые морские воды были вытеснены и на их место проникла вторично пресная вода благодаря наличию трещин, образовавшихся при тектогенезе. Хорошо наслоенные и отличающиеся между собой по характеру пластовые воды говорят за то, что не следует и даже нельзя предположить наличие значительных движений вод (в особенности верти-

кальных) в глубинной зоне. Присутствие и роль ювенильных вод Э. Зюса таким образом не могут быть выявлены. Содержание окиси дейтерия тоже увеличивается по мере увеличения солености вод и глубины седиментационного пространства в зависимости от наличия террестрических солоноватоводных или морских вмещающих пород и содержимых в них вод. Следовательно, это как и химизм воды в определенной степени также является стратиграфическим индикатором.

Мощности осадочных толщ и температуры. В настоящее время для получения термальных вод часто пробуривают в Венгрии скважины глубже даже 2000 м. Мощности отдельных толщ: четвертичная до 250, верхнеплиоценовая 700—800, верхнепаннонская до 1000, нижепаннонская 800—1000, миоценовая 1000—2400, олигоценовая 750—1000, эоценовая до 400 м.

Геотермический градиент составляет 18 м/1° С на территории Большой Венгерской Низменности (к востоку от Дуная), 20—24 м/1° С в Задунайском крае (к западу от Дуная) и 23—26 м/1° С в Северной Венгрии, где распространены главным образом уплотненные породы.

Таким образом, на территории Венгрии геотермический градиент составляет лишь половину или две третьих от нормальной величины градиента в Европе, что весьма благоприятно для вскрытия термальных вод, поэтому оно может быть хорошо использовано. За период от 1952 до 1 июня 1965 г. по нашим гидрогеологическим экспертизам было сооружено 87 термальных колодцев в разных частях страны.

Условия напора подземных вод и области питания.

Опыт показывает, что напор подземных вод изменяется на территории Большой Венгерской Низменности как по вертикали, так и по горизонтали. Вот этими различиями напора и обусловлены направления движения и восполнения пластовых вод, которые на этом основании и могут быть определены (например, на Большой Венгерской Низменности — область Ньиршег и Междуречье Дуная и Тиссы, в Северной Венгрии — горы Бюкк).

Очень важный и с точки зрения водного хозяйства вопрос восполнения артезианских вод Большой Венгерской Низменности сможет быть решен только тогда, когда гидрогеологические условия Карпатских бассейнов в целом — как крупной ландшафтной единицы внутри Карпато-Балканской провинции — будут уже уточнены по единым принципам. Следовательно, считается желательным добиваться этого.

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